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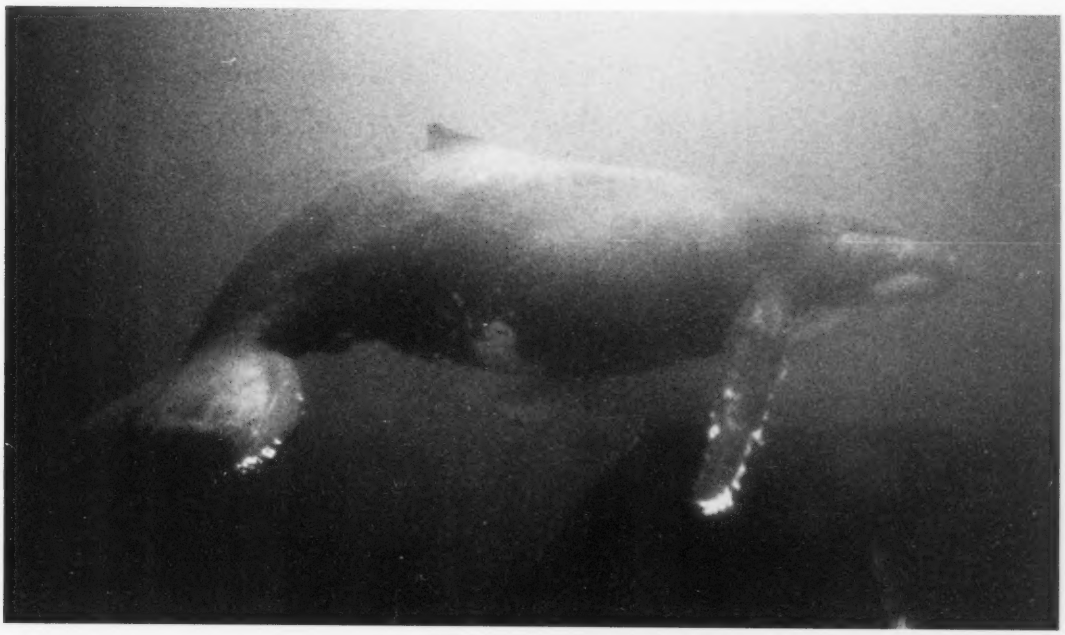

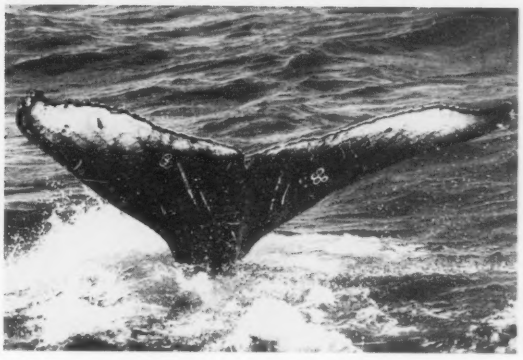

THE HUMPBACK WHALE

Marine Fisheries REVIEW

W. L. Hobart, Editor
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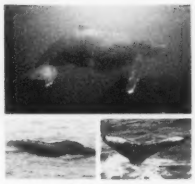
On the cover: Humpback whales. Top photo by R. Wicklund, NURP, NOAA; bottom photos by Sally Mizroch, NMML, NMFS, NOAA.



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Humpback and Fin Whaling in the Gulf of Maine from 1800 to 1918

RANDALL R. REEVES, TIM D. SMITH, ROBERT L. WEBB, JOOKE ROBBINS, and PHILLIP J. CLAPHAM

Introduction

The Gulf of Maine is an oceanic body of water stretching from the coasts of New England and southern New Brunswick in the west to Nova Scotia in the east (Fig. 1). A series of shoals and submerged banks along its southern and eastern margins serve to separate the Gulf from the North Atlantic Ocean. Thus, while the cold, south-flowing Labrador Current is free to enter the Gulf from the north, warm waters of the Gulf Stream are deflected easterly around its southern margin. The circulation of predominantly cold, nutrient-rich water around the complex bathymetric features of the Gulf of Maine enhances its biological productivity (Yentsch et al., 1995). As a result, the region supports a wide range of marine animals, many of which are considered important resources, and large, migratory whales are among them.

Several baleen whale species occur seasonally in the Gulf of Maine, including fin whales, *Balaenoptera physalus*; common minke whales, *B. acutorostrata*; humpback whales, *Megaptera novaeangliae*; sei whales, *B. borealis*; and North Atlantic right whales, *Eubalaena glacialis* (Katona et al., 1983; Kenney and Winn, 1986; CETAP[1]). Exceptionally, blue whales, *B. musculus*, also occur in the Gulf during the summer (Wenzel et al., 1988).

In spite of a few published references to Indian whaling before contact, there is no definitive evidence of it (Little, 1981). There is, however, much evidence that the Indians used the products of whales that stranded or were found floating dead in nearshore waters (e.g. Allen, 1916:145). In fact, it has been suggested that "drift whaling" was an organized pursuit, and that Indians made an organized effort to locate, salvage, and utilize the carcasses of such "drift" whales (Little and Andrews, 1982). Moreover, Indians were extensively involved as crew on colonial whaleboats, and their whaling skills contributed significantly to the development of American shore whaling (Macy, 1835; Little, 1981, 1988).

From the 17th century onward, New Englanders were known as skilled whalers who traveled extensively throughout the North Atlantic (and indeed the world) to hunt whales. It is reasonable to assume that they would have pursued right whales and humpback whales locally to the extent that doing so was feasible and economically rewarding. The most desirable species in the Gulf of Maine would have been the North Atlantic right whale, but it had been reduced to very low numbers there by 1800 (Reeves et al., 1999). The next most likely targets would have been humpback and fin whales, due to their large body size and predictable seasonal availability. Individuals of both species are known to exhibit strong, maternally directed fidelity to the Gulf of Maine (Clapham and Mayo, 1987; Clapham and Seipt, 1991).

While historical data are sparse, today humpback whales occur regularly in the Gulf of Maine from April through October (Clapham and Mayo, 1987; Baraff and Weinrich, 1993; Clapham et al., 1993; CETAP[1]), and feeding aggregations have been observed as late as December in some years (Geraci et al., 1989; Robbins, personal observ.). They are rarely observed between January and March, the peak mating and calving season in the West Indies (Katona and Beard, 1990; Clapham et al., 1993; CETAP[1]). Winter humpback whaling was, in fact, extensive and intensive in

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ABSTRACT—The history of whaling in the Gulf of Maine was reviewed primarily to estimate removals of humpback whales, Megaptera novaeangliae, *especially during the 19th century. In the decades from 1800 to 1860, whaling effort consisted of a few localized, small-scale, shore-based enterprises on the coast of Maine and Cape Cod, Mass. Provincetown and Nantucket schooners occasionally conducted short cruises for humpback whales in New England waters. With the development of bomb-lance technology at mid century, the ease of killing humpback whales and fin whales,* Balaenoptera physalus, *increased. As a result, by the 1870's there was considerable local interest in hunting rorquals (baleen whales in the family Balaenopteridae, which include the humpback and fin whales) in the Gulf of Maine. A few schooners were specially outfitted to take rorquals in the late 1870's and 1880's although their combined annual take was probably no more than a few tens of whales. Also in about 1880, fishing steamers began to be used to hunt whales in the Gulf of Maine. This steamer fishery grew to include about five vessels regularly engaged in whaling by the mid 1880's but dwindled to only one vessel by the end of the decade. Fin whales constituted at least half of the catch, which exceeded 100 animals in some years. In the late 1880's and thereafter, few whales were taken by whaling vessels in the Gulf of Maine.*

[1]CETAP. 1982. A characterization of marine mammals and turtles in the mid- and north Atlantic areas of the U.S. outer continental shelf. Final report of the Cetacean and Turtle Assessment Program, University of Rhode Island, Kingston, R.I., to the U.S. Department of the Interior, Bureau of Land Management, Washington, D.C. Contract AA551-CT8-48, 450 p.

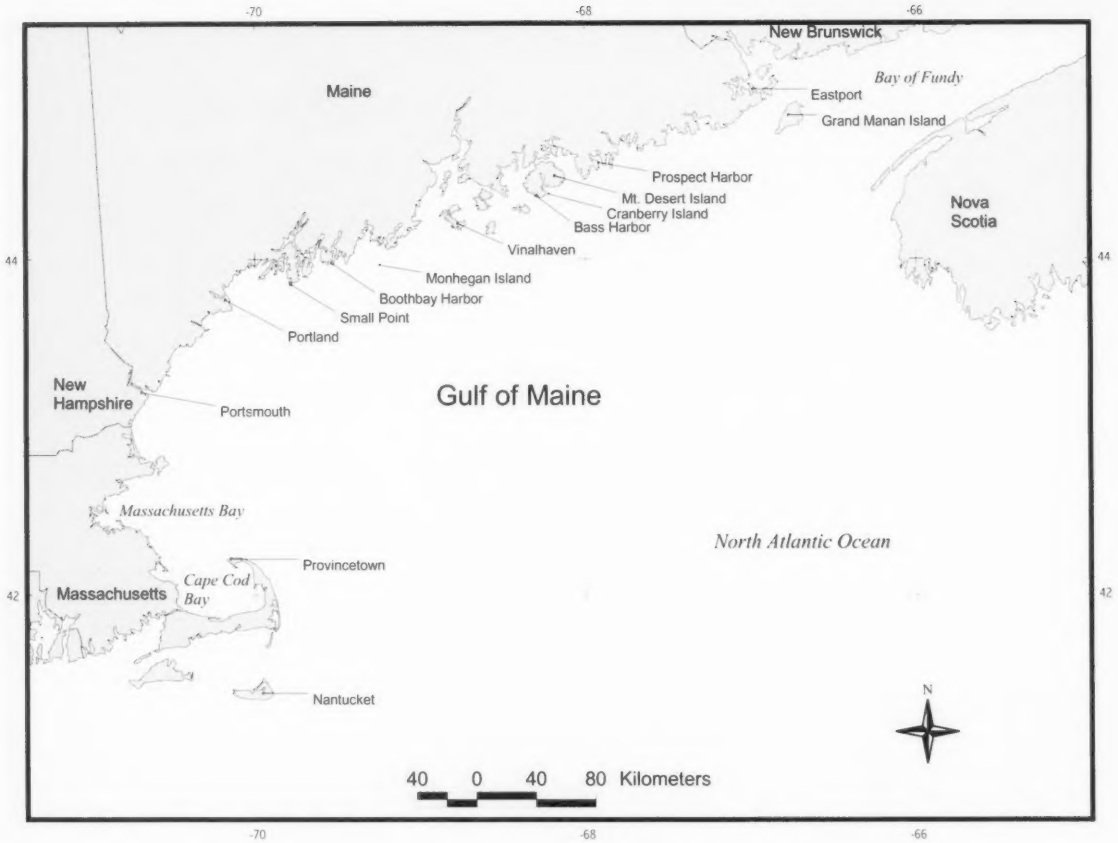

Figure 1.—Map of the Gulf of Maine showing some of the places mentioned in the text.

the eastern and southern West Indies from the 1860's to 1880's (Reeves et al., 2001; Reeves and Smith, 2002), so many Gulf of Maine migrants likely would have been killed at the southern end of their range during the 19th century.

Fin whales are also present in the Gulf of Maine from spring to late fall but are largely absent in the winter (Seipt et al., 1990; Hain et al., 1992; CETAP[1]). Unlike humpback whales, they are not known to follow a strict, long-distance migratory schedule, and their winter distribution appears more diffuse. Also in contrast to humpbacks, the faster-swimming fin whales were generally not hunted before the advent of modern whaling methods, specifically the use of powered catcher boats and explosive projectiles (Tønnessen and Johnsen, 1982). They only became regular prey of whalers in the last third of the 19th century.

Within the Gulf of Maine, humpback and fin whales exhibit habitat-use patterns that would have made them predictably available to be hunted. Their distribution is driven by the habitat preferences of their prey, presently sandlance, *Ammodytes* spp., and Atlantic herring, *Clupea harengus*, although menhaden, *Brevoortia* spp., also may have been important historically (Clark, 1887a; Webb, 2001). As a result, they tend to congregate near discrete bathymetric features, some of which are located close to shore (Hain et al., 1992; Hamazaki, 2002; CETAP[1]). However, the abundance of fin and humpback whales in any one area varies considerably within and between years in response to prey variability, and there is evidence that the two species do not respond to such variability in the same way (Payne et al., 1990). Thus, while the two whale species are roughly sympatric and have consistent habitat preferences, they would not necessarily have been equally available in all areas of the Gulf of Maine.

The Scientific Committee of the International Whaling Commission initiated an assessment of North Atlantic humpback whales in 2001and completed this assessment in 2002 (IWC, 2002, 2003). The Committee used estimates of present-day abundance, estimates of life history parameters from modern fieldwork, and historical catch series to model popu-

Table 1.—Sources in Maine examined by RLW for whaling data.

Institution	Documents	Period	Comments
Boothbay Region Historical Society, Boothbay Harbor	Boothbay *Register* newspaper	Complete run available 1876-late 1880's	Interview with Barbara Skinner Rumsey, Director, who provided newspaper extracts which were then verified by direct examination
Maine State Archives, Augusta	Federal census records for State of Maine	1850, 1860	
Maine State Library, Augusta			No relevant holdings identified
Frenchboro Historical Society, Frenchboro			Interview with Vivian Lunt, Historian
Mount Desert Historical Society, Mount Desert			Interview with Jaylene B. Roths, Director and President
Penobscot Marine Museum, Searsport			Interview with Jon Arrison, Librarian
Tremont Historical Society, Tremont			Interview with Arlene Bartlett, President
www.rootsweb.com/~meccranb/census/	Census records for town of Mount Desert	1800, 1810, 1820, 1830	
Maine Maritime Museum, Bath	*Daily Times* newspaper	Complete run available; checked late 1870's–1880's	Newspaper extracts prepared by Nathan Lipfert, Library Director, in 1975

Table 2.—Sources in Provincetown, Mass., Public Library examined by JR for whaling data.

Documents	Issues/Time Period	Comments
Provincetown Advocate newspaper	2/2/1869, 3/3/69, 4/7/69, 5/5/69, 6/2/69, Dec.1869; 1/5/1870; Jan. 1871, 3/1/71; Jan. 1872; Jan. and Dec. 1873 and 1874; Jan., Feb., and Dec. 1875; Jan. only for 1876-80, 1889, 1905-09	1881–98 and April 1899–1904 issues were unavailable for review; in early years, Jan. issues summarize previous year's whale and fish oil production for Barnstable Co.
Provincetown Banner & News newspaper	July 1856; 1/19/1857, 4/23/57, 4/30/57, 9/10/57, 12/10/57; 2/18/1858, 6/10/58, 6/17/58; 1/13/1859, 10/20/59, 11/24/59, 12/8/59; 6/14/1860, 6/21/60, 11/29/60; 1/3/1861, 5/9/61	All available issues were checked
Provincetown Beacon newspaper	8/2/1890, 9/6/90, 10/25/90	All available issues through 1900 were checked
Provincetown News newspaper	1/7/1871	Only issue available
Books in historic books section	Late 1800's/early 1900's	A few items found to be relevant

lation trajectories and estimate historical abundance (Smith and Reeves, 2002, 2003). Initial results (IWC, 2002) gave improbably low estimates of early abundance for the Gulf of Maine. This paper strives to improve understanding of the catch history of humpback whales in that part of their range. Historical literature was reviewed with the goals of describing the general nature of humpback and fin whaling in the Gulf of Maine from the early 19th century to the early 20th century and obtaining quantitative data on removals over that period. An earlier draft of this paper was used by the IWC Scientific Committee to complete its assessment of North Atlantic humpback whales in 2002 (IWC, 2003).

Materials and Methods

In addition to reviewing the standard period literature, one of us (RLW) conducted a search of archives and libraries in Maine for published and unpublished data on shore whaling in the Gulf of Maine. The sources examined in that search are summarized in Table 1. In addition, individuals with local knowledge were interviewed in Tremont and Day's Ferry, Maine. Of special interest was whaling based at Provincetown, Mass., beginning in the late 1870's. To investigate it, one of us (JR) examined local newspaper archives and other materials at the Provincetown Public Library (Table 2). An earlier search of New Brunswick, Can., sources had revealed meager evidence of shore-based whaling in the lower Bay of Fundy (Reeves and Barto, 1985). An extensive search of libraries, museums, and archives for data on right whale catches along the northeastern coast of the United States had found considerable evidence of shore whaling activities in Massachusetts from the late 17th to mid 18th centuries but little thereafter (Reeves et al., 1999).

Results

Pre-Civil War (1860) Era Whaling

Hostilities associated with the War of Independence (1776–83) forced Nantucket whaling vessels, in particular, to redirect much of their whaling effort away from long-distance voyages and toward shorter, safer cruises in local waters. Since, by the mid 18th century, right whales were relatively scarce, the less desirable but nonetheless catchable humpbacks became frequent targets. For example, Allen (1916:312) cited Macy (1835) to the effect that between the War of Independence and the War of 1812, "the New England whalers continued to take Humpbacks on the shoals to the eastward of Nantucket." Starbuck (1878: 94–95) reported that until 1813 when an English privateer raised havoc with the Nantucket fleet, the people "had fished unmolested both for cod-fish and for humpback whales on the shoals at the eastward of the island, and by this means eked out a livelihood. . . ." Indeed, in 1813 ten small Nantucket vessels, and "several" in 1814, were reportedly whaling for humpbacks on the shoals (Starbuck, 1924:422). The sloops *Rover* and *Success* took two humpback whales during a brief cruise in the last week of September 1815 (Starbuck, 1924:424–5).

Very little is known about whaling in the Gulf of Maine between the War of 1812 and the American Civil War of

1860–65. General statements in Allen (1916), Goode (1884), and the *Whalemen's Shipping List* (1843–1914), however, confirm that humpback whales were taken at least occasionally in local waters by whalers out of Nantucket, Provincetown, and several Maine ports. The data from Clark (1887a), Allen (1916), and Mitchell and Reeves (1983) were reviewed by Reeves and Smith (2002), and specific records from those and other sources are presented in Table 3.

There is some evidence of a small-scale whaling operation on Cranberry Island, Maine. Thomas Spurling's will included a whaleboat and other whaling implements, and a whaleboat oar is preserved on the island (Liebow[2]). Tryworks once stood on Tryhouse Point at the head of Bass Harbor, Maine, in the modern village of Barnard, formerly West Bass Harbor (Kelley[3]).

Mitchell and Reeves (1983) cited the transition in whaling technology from the use of traditional hand-thrown harpoons and oar-powered boats to the use of bomb lances and steam power as an important development in the history of humpback whaling in New England. From the 1860's onward, both fin whales and humpback whales could be taken with relative ease. Together, these species provided a sufficient resource base to support a resurgence in small-scale shore whaling enterprises along portions of the Gulf of Maine. A descendant of the whalers who operated out of Bass Harbor reported that they used a shoulder gun (3 in. diameter barrel, 1 in. bore, brass stock) to kill whales (Kelley[3]). This implies that the shore whalers from Maine participated during the latter part of their fishery (which ended about 1860—see Table 3) in the transition from hand-thrown, nonexplosive harpoons to explosive projectiles generally associated with the mechanical whaling era.

New England's Rorqual Fishery, 1870's–1890's

Two types of vessels—schooners and steamers—were used in the New England rorqual fishery that began in the late 1870's. Again, data from Clark (1887a) and Allen (1916) were reviewed in some detail by Reeves and Smith (2002) and are summarized in Table 3.

Schooner Whaling

Schooners that whaled in the Gulf of Maine were generally 50–75 tons. A 75-ton vessel would normally have a crew of 18 with two whaleboats carrying 6 men each (*American*, 1895). Two vessels that are repeatedly mentioned in the literature are the *Brilliant* and *Bloomer*, both of Provincetown (Mitchell and Reeves, 1983; Reeves and Barto, 1985; Webb, 2001; Reeves and Smith, 2002).

Hegarty's (1959) list of Provincetown voyages in 1879 did not include the *Brilliant*, although this vessel is known to have taken at least four humpback whales in the Gulf of Maine that year. Nor do the sailing dates, return dates, and reported oil landings of the 14 voyages in Hegarty's list suggest that any of them were centered in the Gulf of Maine. Six of the voyages lasted for more than a year. Of the remaining eight, the two voyages by the *Rising Sun* are known to have included whaling for humpback whales in the West Indies or for right whales off Georgia during the winter season (Reeves et al., 2001). The other six voyages all began in winter (January–March) and ended in August or September with at least some sperm oil on board, suggesting an offshore, distant-water North Atlantic itinerary. According to the *Daily Times* (1879), the *Brilliant* was an old pinky schooner that carried only one whaleboat and tried out the oil on shore (Webb, 2001).

The schooner mentioned by Reeves and Smith (2002) as having hunted humpbacks along the Maine coast in 1880 and 1881 was likely the *Bloomer*, noted in the *Whalemen's Shipping List* (1843–1914) to have been "fitted for humpback whaling on the Coast of Maine" but to have taken mainly fin whales in 1880. It was also on the coast of Maine on 12 August 1881 with 75 barrels (bbl) of whale oil on board, then at Southwest Harbor, Maine, with two humpback whales alongside (expected to make 50 bbl of oil) on 29 August 1881 (Reeves and Barto, 1985). Hegarty (1959) listed the *Bloomer* as a 74-ton schooner that sailed from Provincetown on 24 January 1881 and returned 25 September 1881, with no sperm oil and 120 bbl of whale oil. Considering what is known about this voyage's departure date and duration, it is possible that the 75 bbl of whale oil obtained before 12 August came from elsewhere in the North Atlantic (e.g. right whales off the southeastern United States or humpback whales in the Cape Verde Islands or West Indies during the months of January–May).

In 1882 the *Bloomer* was reported at Grand Manan, New Brunswick, Can., on 1 July with 30 bbl of whale oil on board, having taken one humpback whale; it had secured 120 bbl of whale oil for the season by that date (Reeves and Barto, 1985). Hegarty (1959) listed the *Bloomer*'s catch for 1882 as 110 bbl of whale oil and its sailing and arrival dates as 1 June and 5 October, respectively. This schedule, in contrast to that of 1881, would be quite consistent with a Gulf of Maine focus for the 1882 voyage. Two voyages were listed for the *Bloomer* in 1883, one from 13 March–20 August (obtaining 60 bbl of sperm oil and 100 bbl of whale oil) and the other from 17 December 1883–24 August 1884 (obtaining 50 bbl of sperm oil and 15 bbl of whale oil; Hegarty, 1959). The latter voyage included a period in the West Indies, where the *Bloomer* was seen hunting humpback whales in April and May (*Franklin*[4]). Although the *Bloomer* continued whaling for two more years after 1884, its reported production consisted only of sperm oil (Hegarty, 1959).

Menhaden Steamer Whaling

The rorqual fishery by steamers in the Gulf of Maine was intertwined with the menhaden fishery. Indeed, menhaden oil was interchangeable with whale oil (Goode, 1887; Webb, 2001). A series of oil processing factories had been established from the 1840's to the 1860's, producing fish oil for use in tanning and

[2] Liebow, Charles. February 2002. Southwest Harbor, Maine. Personal commun. via R. L. Webb.

[3] Kelley, Harvey. February 2002. Tremont, Maine. Personal commun. via R. L. Webb.

[4] Logbook of the schooner *Franklin* of New Bedford, James F. Avery, Master. 9 October 1883–24 August 1885. Kendall Institute, New Bedford Whaling Museum, New Bedford, Mass.

Table 3.—Gulf of Maine whaling records post-1799. References from Mitchell and Reeves (1983) and Reeves et al. (1999) are designated as * and **, respectively. RW=right whale, FW=fin whale, HB=humpback whale, MW=minke whale, UN=unidentified whale, s/l=struck but lost.

Date[1]	Whales taken[2]	Vessels	Comments	Sources
Apr. 1800	3 RW		At Nantucket; 31, 16, and 30 bbl oil	Allen, 1916:134**
ca. 1805–10		4, with 14-man crews	Wellfleet, Mass., said to hunt humpbacks in Gulf of Maine	Clark, 1887b:235*; Allen, 1916:312
1810–34	<6–7/yr		Shore station, Prospect Harbor, Maine	Clark, 1887a:41
1813		10 small	From Nantucket, humpbacking on Nantucket Shoals	Starbuck, 1924:422*
1814		"Several" small	From Nantucket, humpbacking on Nantucket Shoals	Starbuck, 1924:422*
27–29 Sept. 1815	2 HB	*Rover* and *Success*		Starbuck, 1924:424–425*
Early May 1822	1 RW	Cape Cod vessel	s/l in Boston harbor; species identification uncertain	Allen, 1916:134–135; *Nantucket Inquirer***
Early Aug. 1827	2 HB	Sloop *Rapid* of Nantucket	On the shoals about 20 mi E of Nantucket in 18 fathoms; 50 bbl of oil was expected from the blubber; Capt. Myrick	Allen, 1916:312
5 July 1834	1 FW	Small local boat	Gloucester harbor; s/l; species identification uncertain	Allen, 1916:208
11 Apr. 1835	1 RW	Schooner *Columbia* of Provincetown	75–80 bbl oil expected	*New-Bedford Mercury***
1835–40	6–7/yr UN		Shore station, Prospect Harbor, ME; up to 10 some years.	Clark, 1887a:41
20 May 1836	1 HB or FW	2 Portsmouth boats	35 ft; harpooned off Portsmouth by Nantucket whaleman	Allen, 1916:208
1841–60	<6–7/yr		Shore station, Prospect Harbor, Maine, active	Clark, 1887a:41
1840–60	3 or more/yr UN		Shore station near Tremont, Maine	Clark, 1887a:40
11 May 1843	1 RW	Schooner *Cordelia* of Provincetown	Great South Channel; 125 bbl oil, 300 lb of 14-ft baleen saved; whalers estimated potential yield as 300 bbl and 1500 lb; possibly a bowhead according to Allen	Allen, 1916:135**
July 1844	1 HB		Found dead off Petit Manan Lighthouse, Maine; "perhaps . . . killed by the shore whalers."	Allen, 1916:313
1845	7 HB, 1 FW	Schooner *Huzza* from Maine	Capt. J. Bickford	Clark, 1887a:41
10 Dec. 1846	1 FW		50 ft; in Provincetown harbor	Allen, 1916:208
Oct. 1846	1 HB		Capt Justice W. Bickford; taken into Prospect Harbor; > 100 bbl oil, worth $1500	*American*, 1895
Mid Apr. 1848		5 vessels from Plymouth	Several right whales chased	Allen, 1916:136**
Late Jan.–early Feb. 1850	2 RW		Large (1 of them 50 bbl); in Provincetown harbor	Allen, 1916:136**
1 Nov. 1850	1 RW	3 local boats	60 bbl oil; Provincetown harbor	Allen, 1916:136; Clark, 1887a:41; Goode, 1884:24**
1850		*Vesta* of Provincetown	80 bbl HB oil	Starbuck, 1878:473*
1850	1 HB	*Council* of Provincetown		*Whalemen's Shipping List**
1852	6 HB	*Hamilton* of Nantucket	130 bbl oil; also s/l 5 HB	Allen, 1916:307, 309, 314*
1852		*Hamilton* of Nantucket	60 bbl HB oil	Allen, 1916:314*
1852	1 HB	Provincetown schooner	40 bbl oil	Allen, 1916:314*
Early Oct. 1852	2 UN	Schooner *Union* of Provincetown	In Massachusetts Bay; Allen (p. 314) suspected they were humpbacks based on time of year, but also suggested they were probably right whales (p. 136)	Allen, 1916:136, 314*
Mid May 1852	1 RW	Provincetown vessel	In Massachusetts Bay; 75 bbl oil, 8 ft baleen	Allen, 1916:136**
Oct. 1852	1 UN		Off Cape Elizabeth, Maine; 30 ft; reported as a fin whale, but Allen suspected minke whale	Allen, 1916:275
1853	4 HB		"Shoals whaling"	*Whalemen's Shipping List**
Apr. 1853	2 UN	3–4 Provincetown vessels	Possibly a third s/l; Provincetown harbor; Allen suggested these may have been right whales	Allen, 1916:136–137**
6 July 1854	1 FW		Outside Nantucket harbor; large	Allen, 1916:208
11 Dec. 1854	1 RW	Provincetown vessel (probably)	Drifted ashore at Sandwich bearing harpoon probably affixed in Provincetown harbor; 48 ft, 30–60 bbl oil	Allen, 1916:137; *Nantucket Inquirer*; *Whalemen's Shipping List***
17 Nov. 1855	1 FW	Local boat	s/l off Provincetown	Allen, 1916:208
20 Aug. 1856	1 UN		Small whale killed near Lubec, Maine, after becoming trapped in a herring weir; possibly a minke whale	Allen, 1916:275
1857	1 HB	*Rienzi* of New Bedford		*Whalemen's Shipping List**
15 Apr. 1857	2 FW		s/l off Provincetown	Allen, 1916:209
1858	1 MW		Provincetown, reported as "Grampus Whale"	Allen, 1916:276
Late Nov. 1858			Right whale fired at with harpoon guns in Provincetown harbor	Allen, 1916:137**
1859			180 bbl HB oil	*Whalemen's Shipping List**
17–24 Mar. 1860	1?		Provincetown harbor	*Whalemen's Shipping List**
25 July–early Nov. 1861	5 HB	*Samuel Chase* of Nantucket	125 bbl HB oil	Clark, 1887a:41; Starbuck, 1924:481*

Continued

Table 3.—Continued.

Date[1]	Whales taken[2]	Vessels	Comments	Sources
1861			349 bbl HB oil from "shore and shoals whaling from Prov'town and Nant'et" (probably includes *Samuel Chase*'s production)	*Whalemen's Shipping List**
Aug. 1863		Local boats	"Efforts have been made" to catch a whale seen in Penobscot Bay	Belfast *Republican Journal*, August 1863 (*fide* John Arrison, personal commun. to RLW)
Apr. 1864	1 RW		Off Plymouth, towed to Provincetown; 48 ft, 80 bbl oil, 1,000 lb baleen	Allen, 1916:118, 137, 171; Allen, 1908:322**
1866	1 HB		Portland, Maine, harbor	*Whalemen's Shipping List**
1867–84	2–3 RW		Provincetown	Goode, 1884:24**
1867	1 RW		Cape Cod Bay; 4 8ft, 84 bbl oil, 1,000 lb baleen	Goode, 1884:24**
25 Oct. 1868		Local boat	4 fin whales chased off Nantucket	Allen, 1916:209
Autumn 1868	1 FW	Blackfish [pilot whale] boats	Off Cape Cod; > 60 ft, 20 bbl oil	Allen, 1916:209
1870	1 FW	Vessel from Prospect Harbor, Maine	Capt. J. Bickford	Clark, 1887a:41
1 Mar. 1870	2 RW		Cow/calf; cow lanced but not secured; Provincetown harbor	Allen, 1916:137**
20 Oct. 1870	1 FW		Off Gloucester; 45 ft	Clark, 1887a:41; Allen, 1916:209
Oct. 1871	1 FW		Off Gloucester	Allen, 1916:209
10 Dec. 1872	1 FW	Local boat	S/I in Provincetown harbor	Allen, 1916:210
23 Oct. 1874	4 FW		Shot, killed, but sank in Vineyard Sound, MA (Allen, p. 256, reported that one may have been a blue whale)	Allen, 1916:210
1875	1 HB	Schooner *Starlight*	Cape Cod Bay	Allen, 1916:314*
1878	1 HB		Cape Cod	Allen, 1916:308; True, 1904:232*
1878	1 HB		"Found adrift and towed into Portland Harbor"; "a harpoon embedded in its back, and . . . otherwise lacerated"	Norton, 1930:94–95*
Spring 1879	2 HB		Killed with bomb lances; another stranded; all at Provincetown	Allen, 1916:308, 314; Goode, 1884:27; True, 1904:232*
By 1 Oct. 1879	4 HB	Schooner *Brilliant* of Provincetown	155 bbl oil	Goode, 1884:27*; Clark, 1887a:22; Allen, 1916:314; Webb, 2001
Spring 1880	1 HB		Bass Harbor, Maine; 1,200 gal oil "but no bone of value."	Clark, 1887a:40; Allen, 1916:308, 313*
May 1880	1 UN		Drifted ashore at Small Point near mouth of Kennebec River, Maine, "presumably shot by 'whalers'"	Webb, 2001; *Daily Times*, 1880
1880	(3 HB)		Killed with bomb lances at Provincetown	Clark, 1887a:42*
Spring 1880	6 FW	Provincetown whalers	Found floating in Massachusetts Bay and towed to Gloucester but only 3 were processed and the others discarded (Clark); 4 towed to Gloucester (longest 65 ft) before 13 May (True); one (55 ft) drifted ashore near Gloucester before 23 July (True)	Clark, 1887a:41; True, 1904:63–64
Mar.–mid May 1880	40 mainly FW	Provincetown whalers	38 processed at Jonathan Cook's oil works on Long Point; 2 sold for exhibition (NY and Boston)	Clark, 1887a:41–42
10–15 June 1880	10 mainly FW	Provincetown whalers	Processed at Cook's oil works; at least 10 more were killed but not secured	Clark, 1887a:42
1881	2 HB	Schooner *Bloomer* of Provincetown	*Bloomer* took 5 whales in one summer in early 1880's (*fide* Ralph Stanley, pers. comm. to RLW)	*Whalemen's Shipping List**
1881	(Several HB)		All but 1 killed/sank at Provincetown before 11 April	*Whalemen's Shipping List**
1881	20 HB		Shot with bomb lances at Provincetown; "doubtless others were killed at this time."	Goode, 1884:27; Allen, 1916:308, 314; see *Whalemen's Shipping List* for a different account*
1883	9 mainly FW	Steamer *Fanny Sprague* of Boothbay	Capt. Albert Murray	Webb, 2001; *Daily Times*, 1884
Early Mar.–April 1884	Many mainly FW	4 steamers from Cape Cod and Maine		Allen, 1916:212–213
Before 22 July 1884	19 mainly FW	Steamer *Fanny Sprague* of Boothbay	64 ft largest; a 64 ft specimen was expected to yield 25–30 bbl oil; 18 of the 19 were taken into Provincetown, only one into Linekin; Capt. Albert Murray	Webb, 2001; *Daily Times*, 1884; *Register*, 1884a, 1884b, 1884c
Ca. 10 Feb.–13 Mar. 1885	(7–15 UN)	Steamer *Fannie Sprague* of Boothbay	One towed into Gallup's Factory (Linekin) ca. 26 Feb. (72 ft) (*Times*); 6 shot first week of March, of which 2 were towed to Linekin and 4 that sank were buoyed (True); 3 others plus 2 "buoyed outside" on ca. 13 March, plus 2–3 others sank (*Register*); Capt. Albert Murray	*Daily Times*, 1885a; *Register*, 1885a, 1885b, 1885c; True, 1904: 64
13 Mar.–28 Apr. 1885	(21 mainly FW)	Steamer *Fanny Sprague* of Boothbay	Steam whaling a "regularly organized business" in Gulf of Maine; 8th whale of season delivered to Richardson's (= Gallup's) Factory on ca. 1–2 Apr. (70 ft), shot near Pemaquid; Capt. Albert Murray	Webb, 2001; *Register*, 1885d; *Daily Times*, 1885b
Mar.–Apr. 1885	(Ca. 40 UN all told through April)	4 steamers: *Fannie Sprague*, *Mabel Bird*, *Hurricane*, and *Josephine*		True, 1904:64
Late Apr. 1885	(4 FW)	*Fanny Sprague* (towed to Portland by steam tug *William H. Clark*)	Taken in one day off Provincetown	*Daily Times*, 1885b; *Register*, 1885e
May 1885	(1 UN)	Steamer *Mabel Bird* of Boothbay	Whale carcass exhibited in Portland	Webb, 2001; *Register*, 1885f

Continued

Table 3.—Continued.

Date[1]	Whales taken[2]	Vessels	Comments	Sources
June 1885			*Fanny Sprague* 'has taken twenty-six or more finbacks off the Maine coast since February.'	*Register*, 1885g
Ca. mid June 1885	(1 UN)		Shot and towed to Portland for exhibition; probably a fin whale	*Register*, 1885h
Before 7 July 1885	(37 mainly FW)	Joshua Nickerson		Allen, 1916:229; Webb, 2001
20 May 1885			Whaling suspended at Boothbay because of stench	*Daily Times*, 1885c
Mid to late May 1885	(1 UN)	Steamer *Valora*, Capt. Haskell	For Boothbay oil plant, or to exhibit in Portland; probably a fin whale	*Daily Times*, 1885d
3 July 1885	1 FW		Stranded at Mt Desert Light Station, probably had been shot by a whaling steamer	Allen, 1916:229
7 July 1885	(1 FW)	Joshua Nickerson	In Massachusetts Bay	Allen, 1916:213, 229
Early–mid July 1885	(3–4 UN)		For Richardson's Factory, flensed on Heron Island	*Register*, 1885i
1885			Total catch by all 5 steamers operating: about 75, mainly FW	Allen, 1916:229; True, 1904:65
By 30 Sept. 1885	Ca. 100 FW and HB		Season finished on Maine coast (steamer whaling)—season's catch ca. 100; humpback described as main target, yielding 20–30 bbl	*Daily Times*, 1885e
1885			Whaling station established on Greene's Island, Maine, by Gen. Davis Tilson and Maj. W. S. White of Rockland	Calderwood, 1972:89–94
20 Feb. 1886		New steamer, prob. *Angelia B. Nickerson*, Boothbay	Began whaling season	*Daily Times*, 1886a; Webb, 2001
Mid March 1886		Steamer *Ressing*	Left to cruise for whales in Bay of Fundy; Capt. Murray	*Register*, 1886a
By 10 Apr. 1886	(3 UN)	Steamer *Ressing*	Towed to Richardson's Factory; Capt. Murray	*Register*, 1886b
Mid May 1886			Whales said to be "scarce" between Nantucket and Monhegan	*Register*, 1886c
Ca. 27 May 1886	(2 UN)	*Ressing*	Capt. Murray	*Register*, 1886d
Late May/early June 1886	(4 UN)	*Ressing*, *Murray*	Towed to Linekin (Gallup's Factory under Horace R. Tewksbury)	*Daily Times*, 1886b; *Register*, 1886e
June 1886	(Some UN mainly FW)	3 steamers, including *Herman Reessing*	Cruising between Eastport and Cape Cod; "many that are shot and sink in deep water are not recovered" (True)	Allen, 1916:213–214; Webb, 2001; *Register*, 1886f; True, 1904:64
Before 30 June 1886	(1 UN)	Fishing steamer *Nellie B. Rawson*	For exhibit in Bangor, ME; Luther Maddocks	Webb, 2001; *Daily Times*, 1886c
Before 10 July 1886	90 UN mainly FW	Steamer *Herman Reessing*	". . . the sharks have fed on most of them."	*Register*, 1886g
1886	4 RW		125 bbl oil; 1,500–2,000 lb baleen; at Nantucket and Tuckernuck	Allen, 1916:126–128, 138, 171; *Whalemen's Shipping List*; Stackpole, 1982**
10 July 1887	1 UN	Local boat	Near Wauwinet, Mass.; probably a minke	Allen, 1916:276–277
1887	1 RW		Provincetown; male; 47 ft, 70 bbl oil	Allen, 1916:138**
1887	52 UN	Steamer *A.B. Nickerson*	Delivered to Provincetown oil works; probably FW and HB	Allen, 1916:230
1887	ca. 50 UN	Vessels other than *A.B. Nickerson*	Delivered to Provincetown oil works; probably FW and HB	Allen, 1916:230
20 Apr. 1888			UN (possibly FW) chased by Nantucket whalers	Allen, 1916:214
20 May 1888	2 RW		Massachusetts Bay, combined 170 bbl oil	Allen, 1916:138–139; *Whalemen's Shipping List***
May 1888	1 RW	Steamer *A.B. Nickerson* (probably)	Provincetown; whale found dead on Georges Bank; 50 ft	Allen, 1916:139; *Whalemen's Shipping List***
1 June 1888	2 RW	Steamer *A.B. Nickerson*	Cow–calf pair bomb-lanced near Provincetown; cow 55–60 ft, 100 bbl oil, 1,500 lb baleen; calf sank	Allen, 1916:130–131, 139, 143, 171; *Whalemen's Shipping List***
5 June 1888	1 FW	Steamer *A.B. Nickerson*	Large; sank	Allen, 1916:214, 229–230
1 May 1890	1 FW	Provincetown vessel	Found floating and towed to Lynn, Mass.	Allen, 1916:214, 230
12 Sept. 1894	1 FW		Off the 'Gully'; Capt E.W. Smith of Provincetown	Allen, 1916:214, 230
Late Sept. 1894	1–2 FW	Provincetown vessels		Allen, 1916:214
Late Mar. 1895	1 RW		Initially escaped towing gear; off Nahant; found dead at sea N of Provincetown; 42 ft, 50–60 bbl oil, 5.5 ft baleen	Allen, 1916:120, 139; True, 1904: 268**
12 Apr. 1895	1 FW		Massachusetts Bay; Capt E.W. Smith of Provincetown	Allen, 1916:214, 230
12 Apr.–16 May 1895	5 FW, 3 UN	*A.B. Nickerson* of Provincetown	Delivered to oil factory at Herring Cove, Provincetown (Joshua G. Nickerson, owner)	Allen, 1916:214, 230; Webb, 2001 (from *Nantucket Journal*)
1895	1 FW	Steamer *Vigilant*	Capt. Fuller; embalmed and exhibited (in Boston?); species identification uncertain	Allen, 1916:230; Webb, 2001
Early May 1895	2–3 FW	Vessels other than *A.B. Nickerson*		Allen, 1916:214
1895	1 HB		Capt E.W. Smith of Provincetown; struck/lost at Provincetown	Allen, 1916:308, 315*
Before 23 Apr. 1896	2 HB, 2 UN	Steamer *A.B. Nickerson* of Provincetown		Allen, 1916:230; Webb, 2001
23 Apr. 1896	2 FW	Provincetown vessels	Off Cape Cod	Allen, 1916:215
Late Sept. 1896	1 FW		Stranded at Nantasket Beach, Mass.; thought to have been shot by whalers	Allen, 1916:230
15 Jan. 1909	1 RW		11-m female entangled in fish-trap, killed with bomb lance	Allen, 1916:119, 140**

[1] "By" a certain date indicates authors' judgment that the information refers to what transpired in this season to the given date.
[2] Parentheses indicate authors' judgment that this record is subsumed within another.

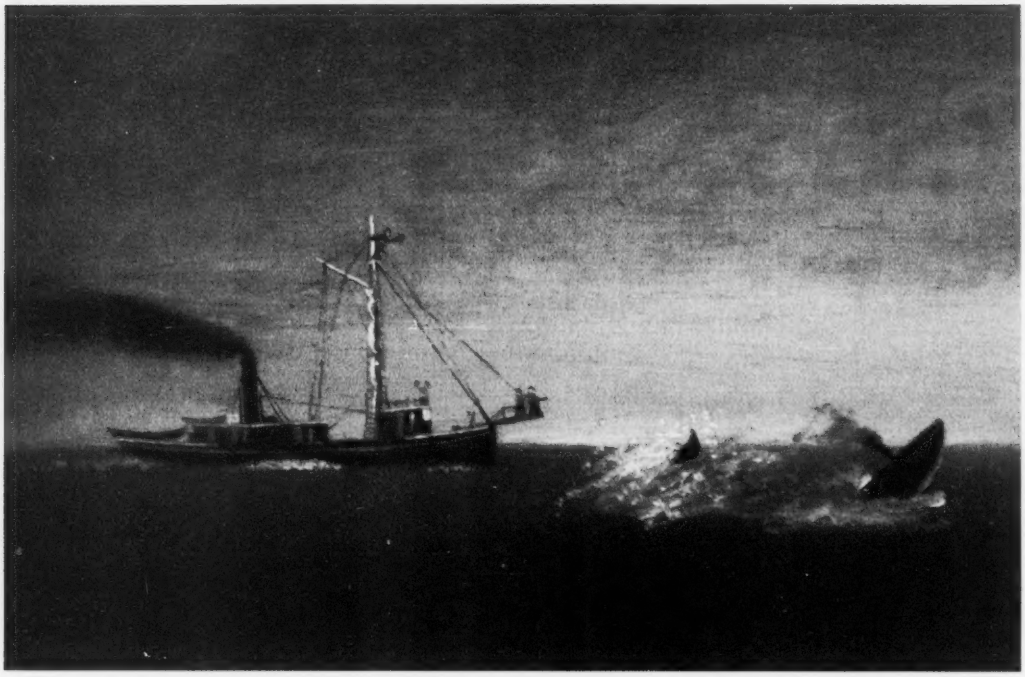

Figure 2.—The menhaden steamer *Angelia B. Nickerson* closing on a rorqual that has been shot and is spouting blood, somewhere in the Gulf of Maine. Courtesy of the Fall River Marine Museum.

curing leathers. When the availability of menhaden declined sharply in the Gulf during the late 1870's, some fishermen turned to whaling.

The steamer *Mabel Bird* was converted from menhaden fishing to whaling in 1880. It hunted humpback whales off Monhegan Island, Maine, and the carcasses were towed to an oil processing plant at the head of Linekin Bay in Boothbay Harbor (Maddocks, 1926; Webb, 2001). This was probably one of the earliest, if not the earliest, steam whaler to operate in the Gulf of Maine. Within a few years, at least five oil factories in Boothbay Harbor were processing whales. One was owned by Luther Maddocks (at least during 1880–85); the others were the Maine Oil Company and Cumberland Bone Company on Spruce Point; Suffolk Oil Works on the opposite side of the head of the bay; Richardson Fish Oil Works to the south of there; and a nearby plant operated by Alonzo R. Nickerson and his brothers (Greene, 1906; Webb, 2001). Another Boothbay steamer, the *Fanny Sprague* (Captain Albert Murray), was heavily involved in whaling during the mid 1880's, but most of the whales taken were towed into Provincetown for processing (Webb, 2001). It cannot be assumed that the whaling steamers engaged in whaling fulltime during the whaling season. In fact, in 1885 the *Fanny Sprague* caught 245 bbl of mackerel one week and took a large fin whale the next week. The previous year the *Sprague* had taken nine whales while "intermittently" seining fish, amounting to a total of 6,000 lb of menhaden (Webb, 2001).

The largest number of steamers actively whaling in any one year seems to have been about five. Four (Wilcox, 1885) or five (True, 1904:65) were engaged in 1885 and three in 1886 (Wilcox, 1886; True, 1904:65). The vessels involved in 1885 included the *Mabel Bird* registered in Portland, Maine; the *Hurricane* registered in Rockland, Maine; the *Fannie Sprague* registered in New London, Conn.; and the *Josephine* registered in Norwalk, Conn. (Webb, 2001). A fifth vessel, the *A.B. Nickerson* (= *Angelia B. Nickerson*), was registered in Providence, R.I. (Webb, 2001; Fig. 2). In 1886 the *Herman Reessing* (variously spelled) of Eastport was added to the whaling fleet operating out of Boothbay (Reeves and Barto, 1985; Webb, 2001). Several additional steamers are known to have taken whales at least occasionally, including the *Valora* in 1885, the *Nellie B. Rawson* in 1886, and the *Vigilant* in 1895 (Table 3).

The Maine component of the fishery in 1885 produced 36,000 gal of whale oil, 2,000 lb of baleen, and "other products" both liquid and solid, with the total value listed as $23,066 (*Register*, 1885). This report was dated 30 September 1885 but it is impossible to ascertain whether the production was for the year to date, or only for the month of September. The former seems more plausible given that

36,000 gal represents about 1,143 bbl, equivalent to 57 rorquals at 20 bbl/whale or 38 at 30 bbl/whale. Given other information on the returns in 1885 (Table 3), it seems plausible that 40–60 whales would have been delivered to the Maine stations between February and September that year. Some of the carcasses from whales killed in this fishery were boiled and made into "scrap," which was sold dry for $22/ton, "the only objection to it being the large percentage of oil which it contains" (True, 1904:65).

With the return of menhaden to the Gulf of Maine in 1886, steamer whaling lost its appeal and most of the steamers returned to fulltime fishing. As Webb (2001:286) concluded, whaling "merely served as a stopgap while awaiting the fish, and was quickly abandoned when they returned." In September 1887, one of the Boothbay oil factories that had processed many of the whales taken by the steamers changed hands (*Register*, 1887), and the evidence overall suggests that there was a sharp decline in the numbers of rorquals taken after 1886 (Table 3). Although some Provincetown, Mass., whalers, including the steamer *A. B. Nickerson*, were still engaged in whaling in local waters as late as 1896, it is clear that this activity had essentially ended within a few years thereafter (Allen, 1916). When several fin whales entered Provincetown Harbor on 1 March 1899, and two more came in a fortnight later, the many fishermen present "made no attempt to capture them" (Allen, 1916). Similarly, whales observed near Provincetown and Nantucket in 1901 were not molested (Allen, 1916).

A whaling station was established on Greene Island near Vinalhaven, Maine, in 1885 and another at Carver's Harbor, also on Vinalhaven, sometime after 1900, apparently at about the time of World War I (Calderwood, 1972; Webb, 2001). Nothing is known about catches at these sites, but a contemporary photographic postcard depicts a humpback whale, dead and bloated, at the Carver's Harbor station (Webb, personal observ.). That station employed Portuguese flensers, and its catcher vessel was the *Palm*, a 51-ft gas-powered yacht (Calderwood, 1972; Webb, 2001). The kill of a stranded fin whale by Indians near Eastport, Maine, in January 1912 (Allen, 1916) appears to have been exceptional.

Whaling Grounds

Whales were killed in many parts of the Gulf, but a few specific areas were mentioned as especially productive. The whalemen based at Prospect Harbor, Maine, found fin and humpback whales on Jones' Grounds and Schoodic Ridge and along the coast to Monhegan Island (*American*, 1895). The Linekin Bay whalers apparently found an area about three miles west of Monhegan Island to be highly productive. In addition to the 1880 report regarding the *Mabel Bird* (above), the *Fanny Sprague* killed one of about seven or eight fin whales encountered at this site in mid July 1884 (*Daily Times*, 1884). A very large humpback was taken in October 1846 between Monhegan and George's Islands (*American*, 1895). The same whaler took a 45-bbl, 45-ft whale (species not indicated) on German Bank (off the southwestern shore of Nova Scotia, centered at about lat. 66°30′N, long. 43°20′W) and a 20-bbl, 96-ft fin whale between the Schoodic Ridges (near Mount Desert Rock, Maine) and German Bank. He was knocked out of his boat by a whale on the outer ridge, some 50 miles off Mount Desert, Maine. Both German Bank and the Schoodic Ridges remain good areas for observing fin and humpback whales (Clapham, personal observ.). Shore whalers in Maine hunted fin whales to the south of Seal ("Sial") Island and off Mount Desert Rock during the early 20th century (Calderwood, 1972).

There was a great advantage to whaling in shallow water because the deeper the water, the poorer were the chances of retrieving whales that sank (see below). It was claimed in 1885 that the whales were responding to whaling pressure by moving into deeper water, and there was concern that this would make the fishery unfeasible. "After being killed, they usually sink, and it is doubtful if the business, as at present conducted, will last if the whales are driven off from near shore, it being difficult to recover them in over 40 fathoms of water" (True, 1904:64).

Seasonality

Whaling was conducted in the Gulf of Maine in all months, at least on an opportunistic basis. In most years, steamer whaling began in February or March and continued into November (Table 3). There is a suggestion in the data that fin whales, at least, were available in sufficient numbers throughout the spring and summer months to sustain the fishery. Too few of the records, however, had both date of capture and species identification, so no rigorous comparative analysis of seasonal trends in the proportions of fin and humpback whales in the catches was possible.

Hunting Loss

Bomb lances were associated with high loss rates in both schooner and steamer whaling (Reeves and Smith, 2002). Therefore, any estimates of landings need to be adjusted to account for hunting loss (i.e. whales that were struck but not secured). In some respects this was a shoot-and-salvage fishery. In fact, in the summer of 1886 a reward was being offered by one of the oil factories at Linekin, Maine, "for news leading to recovery of drift whales" (*Register*, 1886f). Although the American open-boat whalers had developed special techniques and devices for "raising" humpback and fin whales that sank (Brown, 1887: 270–271), no evidence was found to suggest that these were used in the Gulf of Maine. In attempting to estimate the total kill, it is important to avoid "double counting," which would result if one were to register individual whales that were reported as salvaged without somehow deducting them from the estimated or inferred struck/lost component.

Discussion

Species Composition of Catches

There was a clear historical progression in the Gulf of Maine, as elsewhere in the world, from an early preference for right whales, to more frequent catching of humpback whales as right whales became scarce, and finally to taking other rorquals as well (mainly fin whales) once the technology for doing so had become

available. An important consideration is that although the rorqual fishery in the Gulf of Maine during the second half of the 19th century probably took few right whales, the whalers certainly would have attempted to take any they encountered.

Therefore, the lack of reports of right whales reinforces the conclusion that very few of them remained in the Gulf of Maine by the 1880's (Reeves, 2001). During the entire 19th century, humpback and fin whales appear to have been the principal species taken in the Gulf (*American*, 1895).

More than half of the kill throughout the 1880's probably consisted of fin whales, and humpbacks may have constituted less than about a quarter of the total whale kill during that decade. The Provincetown catch of about 100 whales in 1880, for example, included only 3 humpbacks and the rest were fin whales (Clark, 1887a). This ratio, however, may not have applied to the Maine whalers. One authority with first-hand experience in steamer whaling reported that he took primarily humpbacks (Maddocks, 1926; Webb, 2001), and, according to another source, a humpback was "much more valuable than a finback, yielding twice as much of oil for the same size of creature" (Clark, 1887a:45). Although newspaper accounts are not particularly reliable on such matters, they tended to regard the humpback as the principal target species in Maine (*Daily Times*, 1885e).

It is uncertain whether, or to what degree, the rorqual whalers selected one species over the other. Although humpbacks (1) would have been easier to approach than fin whales, (2) would have produced more oil per unit of length, and (3) may have sunk less often after being killed, there is no clear evidence that the steam whalers hunted them preferentially. It is possible that the catch composition was affected by the relative seasonal availability of the two species. Fin whales could have been present during the entire whaling season from late winter to late autumn, while humpbacks would not have been available until they arrived from their southern wintering areas in late spring. Indeed, the 40 whales taken by steamers early in the 1885 season (March–April) averaged 60 ft long and 25 tons in weight, yielding 20 bbl of oil, 2 bbl of meat, 5 tons of "dry chum," and 2 tons of bone (baleen), for an average value of $400/whale (Wilcox, 1885; True, 1904:64). Based on this description, these likely were all or mostly fin whales.

An alternative explanation of the predominance of fin whales in late 19th century catches might be found in the different catch histories of the two species. Humpbacks had been exploited relatively intensively over much of their North Atlantic range prior to the introduction of steam power and explosive projectiles (Reeves and Smith, 2002), whereas fin whales only began to be killed in significant numbers in the late 1860's and 1870's as modern whaling methods became increasingly available (Tønnessen and Johnsen, 1982). It is therefore possible that humpbacks had simply become less available in the Gulf of Maine by the 1870's and 1880's because of their longer history of exploitation.

Opportunistic vs. Dedicated Whaling

Some of the records of "whaling" listed in Table 3 refer to instances in which whalers or fishermen, who were either idle or engaged in nonwhaling activities, chased and attempted to kill whales that they encountered opportunistically. Interpretation of the historical record must therefore attempt to discriminate evidence of purposeful whaling activity directed at particular target species ("dedicated whaling"), from evidence that indicates the less deliberate search for and pursuit of such species ("opportunistic whaling").

There is also some ambiguity associated with incidents involving entanglement or entrapment in fishing gear. For example, in cases where minke whales were reported as being "captured" (Allen, 1916), it is probably more likely that they were "by-caught" in fishing gear than harpooned while freely swimming. In fact, of the 25 minke whale records mentioned by Allen (1916) from 1849 to 1913, no fewer than 9 explicitly involved capture in fishing weirs.

Removals of Humpback Whales by Whaling in the Gulf of Maine

No good time-series of catch data exists for the Gulf of Maine. The available data are often equivocal concerning numbers and species taken. Nevertheless, there is sufficient anecdotal information on whaling activity to conclude that humpback whales were hunted at least on a small scale throughout the 19th century. Small-scale, shore-based whaling enterprises existed along the coasts of Maine and Massachusetts from the early 1800's to the 1860's, but their combined annual catches of humpback whales may not have exceeded 10–20 animals. Whale ships, as opposed to whaleboats, from Provincetown and Nantucket are known to have conducted short cruises on Nantucket Shoals and elsewhere in the Gulf of Maine from time to time, but the evidence for such whaling is sporadic and essentially anecdotal. Again, catch levels for these vessels appear to have been in the single digits or low tens, at the most, in any single year.

The introduction of bomb-lance technology in the 1850's and 1860's made it easier to kill both humpback whales and fin whales, and by the 1870's the scale of removals of fin whales would have increased greatly. The same may also be true of humpback whales, but there is no conclusive evidence one way or the other. Schooners were outfitted to hunt rorquals in the late 1870's and 1880's, and they probably took a few tens of humpback whales in some years.

In about 1880, fishing steamers began to hunt whales in the Gulf of Maine. This steamer fishery grew to include about five vessels by the mid 1880's but quickly dwindled to only one vessel after menhaden returned to the Gulf in large numbers in 1886. Fin whales constituted at least half of the catch by the steamers, and the total number of humpback whales taken in any year (including secured and shot/lost whales, combined) was probably fewer than 100. Inferences about changes in whaling effort and catch could be confounded by the fact that newspapers and other printed sources were themselves

expanding with time, perhaps thereby increasing the likelihood that whaling activities would be recorded. As noted in Table 2, few Provincetown newspapers published between 1880 and 1904 were available for review. If those materials could be found and examined, it might provide better documentation of catches during that period. Otherwise, however, there is no obvious approach to improving our current fragmentary state of knowledge.

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_____ . 1884. The whale; our special interviews the captain of the steamer which captured him; and inspects the monster. Bath, Maine. 22 July.

_____ . 1885a. Bath, Maine. 17 March.

_____ . 1885b. Bath, Maine. 30 April.

_____ . 1885c. Bath, Maine. 21 May.

_____ . 1885d. Bath, Maine. 25 May.

_____ . 1885e. Bath, Maine. 12 November

_____ . 1886a. Bath, Maine. 26 February.

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Precious Corals in Hawaii: Discovery of a New Bed and Revised Management Measures for Existing Beds

RICHARD W. GRIGG

Introduction and History of Hawaii's Precious Coral Fishery

Precious corals, *Corallium* spp., were first discovered in the Hawaiian Islands in 1900 on one of the *Albatross* expeditions (Bayer, 1956); however, it wasn't until the middle 1960's that commercial quantities were found and exploited. In 1965, Japanese fishermen discovered a huge bed of *Corallium secundum* at depths of 400 m on the Milwaukee Banks (Koko Seamount), about 750 km northwest of Midway Island (Grigg, 1974). In the following year, Vernon Brock and Theodore Chamberlain, of the University of Hawaii, discovered a small bed of *Corallium secundum* off Makapuu, Oahu in the main Hawaiian Islands, again at depths near 400 m (Grigg, 1974, 1993) (Fig. 1). The former discovery by the Japanese fueled a coral rush to the Emperor Seamounts that lasted about 20 years. During the peak years of this fishery, over 100 coral boats from Japan and Taiwan harvested up to 200,000 kg of *Corallium* annually from these seamounts (Grigg, 1974, 1982). Also during the peak years, a second undescribed species of *Corallium* was found in rich abundance at depths of 1,000–1,500 m. On the world market, both of these species are known as "Midway coral."

In 1966, a much smaller fishery was also initiated in the main Hawaiian Islands, in response to the discovery of *C. secundum* off Makapuu, Oahu, in the Molokai Channel (Fig.1). Between 1966 and 1969, about 2,000 kg of *C. secundum* was harvested in the Makapuu Bed by domestic vessels utilizing tangle net dredges (dredges consisting of heavy stones or iron bars with attached netting) (Poh, 1971).

Although the quantity of precious coral harvested in the Makapuu Bed was not great, it was sufficient to stimulate a long-term Sea Grant research program at the University of Hawaii. In the early 1970's, this program developed and deployed technology that permitted selective harvest by a manned submersible (Thompson, 1975). This technology was first utilized commercially by Maui Divers of Hawaii.[1] Maui Divers maintained a precious coral harvesting operation in the Makapuu Bed between 1972 and 1979. During this time, a Federal Fishery Management Plan (FMP) was written by the Western Pacific Regional Fisheries Management Council (USDOC, 1980).

Finalized in 1983, the FMP allowed for selective harvest of up to 2,000 kg/2-year period of *C. secundum*, and, inter-alia, established a 10-inch minimum size limit. Both Federal and state permits were required to harvest the coral. The FMP also permitted harvest of two other species of precious coral from the Makapuu Bed; 600 kg of gold coral (*Gerardia* sp.) and 600 kg of bamboo coral (*Lepidisis olapa*). Both species were discovered in the Makapuu Bed by early Sea Grant research in 1970 (Grigg, 1974).

The Maui Divers operation on the Makapuu Bed flourished for about seven years but was discontinued in 1979 mainly due to increasing costs. A diving accident during the launch of the Star II submersible in the summer of 1975, which resulted in the death of two Maui Divers employees, also contributed to the closure.

For the next 20 years, the precious coral industry in Hawaii relied on imports of *Corallium* species of pink and red coral from Taiwan and Japan. During this time, the only precious corals harvested locally were the black corals, *Antipathes dichotoma* and *Antipathes grandis*. Both species are harvested by scuba divers at depths of 40–75 m in the main Hawaiian Islands. Grigg (2001) recently reviewed the history and management of the black coral fishery since its beginning in 1958.

In 1999, the precious coral fishery for deepwater red, pink, and gold corals in Hawaii was revived. The need to re-establish a local source of pink, red, and gold

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ABSTRACT—The fishery for deepwater precious corals in the Hawaiian Islands has experienced an on-and-off history for almost 40 years. In spite of this, research, driven primarily by the precious coral jewelry industry, remains active. In this paper, the results of deepwater surveys in 2000 and 2001 are reported. In summary, a new bed on the summit of Cross Seamount is described and revised estimates of MSY's for pink coral, Corallium secundum*; red coral,* Corallium regale*; and gold coral,* Gerardia *sp., in the two known beds off Makapuu, Oahu, and Keahole Point, Hawaii, in the main Hawaiian Islands, are presented. The population dynamics of each species is described, as well as their ecological limits on Hawaii's deep reefs, island shelves, and seamounts. The local supply of precious coral in the main Hawaiian Islands is sufficient to support the local industry, but cost/benefits of selective harvest requirements and weather constraints limit profitability of the fishery.*

[1] Mention of trade names and commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

coral and the availability of a new and more cost-effective technology prompted American Deepwater Engineering (ADE), a U.S. corporation, to apply for and receive two permits to harvest deepwater precious corals utilizing two one-man submersibles (Deepworker-2000). The first permit was for the Makapuu Bed and allowed for selective harvest of up to 2,000 kg/2 years of *C. secundum*. The second permit was an Exploratory Area Permit (EAP) that permitted harvest in exploratory areas and allowed selective harvest of up to 1,000 kg of all species of deepwater precious coral combined.

During the 1999–2000 season, ADE, operating under both permits, harvested 1,216 kg of *C. secundum* from the Makapuu Bed, and 150 kg of *Gerardia* sp. and 61 kg of *C. regale* from exploratory areas off Kailua, Kona. The average prices obtained at auction for these three species were $187/kg for *C. secundum*, $400/kg for *Gerardia*, and $880/kg for *C. regale*, respectively.

Despite the Deepworker-2000 technology, operational costs remained high, in part because safety concerns required that two submersibles be operated in tandem. Diving was also limited by weather conditions to a sea state less than 5 and channel winds less than 20 kns. Diving operations were limited to just 20% of the time in each year. As experienced earlier by Maui Divers of Hawaii in the 1970's, profits were reduced by logistic constraints, ultimately producing a marginal return on investment.

Then in late 2000, President William J. Clinton issued Executive Order 13196 to establish a Coral Reef Ecosystem Reserve in the Northwestern Hawaiian Islands (NWHI). This effectively eliminated the entire NWHI (84 million acres) as potential grounds for deepwater precious coral exploration and harvest because two-thirds of the deepwater habitat for precious corals in the State of Hawaii is found in the NWHI. Given this reduction in potential supply and the marginal profits from harvest in 1999–2000, the Board of Directors of ADE elected to suspend precious coral operations at the end of 2001.

In spite of the on-and-off history of the deepwater precious coral fishery in Hawaii, research dealing with the ecology and management of the major species continued over the years and remains active. In recent years, attention has been focused on 1) evaluating impacts of past fishing activities on target stocks in the Makapuu and Keahole Point Beds, 2) assessing harvesting impacts on associated species, e.g. monk seals (Parrish et al., 2002), 3) refining estimates of MSY in known beds, and 4) exploration for new beds and estimating MSY's of species of precious coral that are found there. In this paper, recent progress is reported regarding objectives one, three, and four.

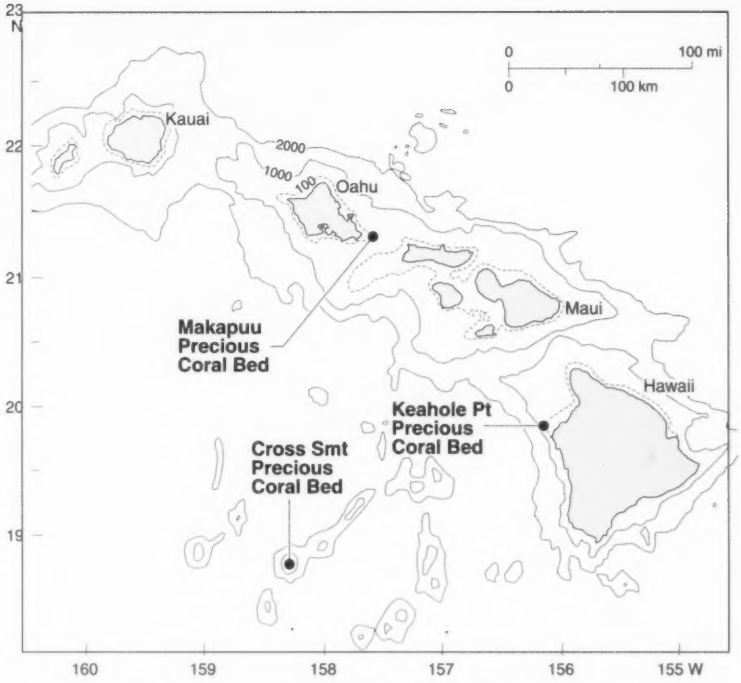

Figure 1.—The main Hawaiian Islands and location of the three known precious coral beds.

Table 1.—Precious coral research dives in 2000–01.

Location	Date	Technology	Dive no.	Depth (m)	Area surveyed (m^2)
Makapuu	10 Nov 01	Pisces IV	PIV-035	396–426	18,500
	11 Nov 01	Pisces IV	PIV-036	390–430	26,000
	10 Nov 01	ROV	RCV-120	315–485	17,000
	11 Nov 01	ROV	RCV-121	331–468	8,000
Cross Smt.	16 Nov 00	Pisces IV	PIV-014	336–458	27,000
	06 Nov 01	Pisces IV	PIV-032	354–421	13,000
	07 Nov 01	Pisces IV	PIV-033	343–445	31,500
	07 Nov 01	ROV	RCV-119	378–485	1,250
Keahole Pt.	19 Nov 00	Pisces IV	PIV-016	360–485	16,000
	05 Nov 01	Pisces IV	PIV-031	380–452	24,500

Methods

Deepwater precious corals in the main Hawaiian Islands are found at depths of 380 to 475 m. Data collection therefore requires remote controlled vehicles (RCV's) and/or submersible technology. Data in this paper was collected during seven dives in the Pisces IV submersible and three deployments of the University of Hawaii Undersea Laboratory's RCV-150 during 2000–01 (Table 1).

Pisces dives and RCV tracks were recorded in real time by the mothership R/V *Kaimikai-o-Kanoloa (KOK)* utilizing a combination of GPS and radar. Tracking of the submersible was accomplished with an ORE Trackpoint II acoustic navigation system. The RCV-150 is controlled from the ship by way of a tethered cable with a depth limit of 900 m. Video-audio tapes were recorded in the submersible using two external video cameras during the entirety of all dives. In the case of the ROV transects, video records were recorded in the ship's tracking room. Video-tapes recorded in the submersible are back-up to visual observations made by science observers in the submersible. Visual records include estimates of abundance, density, condition (percent of coral alive, incidence of disease, evidence of predation, etc.), and size frequency of precious corals. Estimates of density were based on the average number of colonies counted per 100 m^2 in 25 different sections of each bed. Linear tracking eliminated the problem of pseudo-replication. Evidence of recent past harvesting was based on observations of fallen and broken coral colonies in a localized pattern.

Colony size was measured with the aid of two laser lights projected in parallel (calibrated 15 cm apart) on benthic or coral surfaces. Other observations included type substratum, bottom steepness, depth, temperature, salinity, and current speed and direction. In situ collections are also possible during submersible dives using a robotic arm, claw, and basket assembly mounted on the submersible. A Sea Beam 210 multibeam sonar system on the *KOK* was used for precision bathymetric mapping.

Size-frequency distributions of coral colonies were converted to age-frequency distributions simply by dividing colony heights by estimates of linear growth rates for given species (Grigg, 1976). Recruitment and mortality, as well as impacts due to harvesting were estimated by interpreting changes in the age-frequency distributions of *Corallium* or *Gerardia* over time in the same area (Fig. 2). Revisions of MSY were calculated by pro-rating existing estimates by increases in bed area, or by application

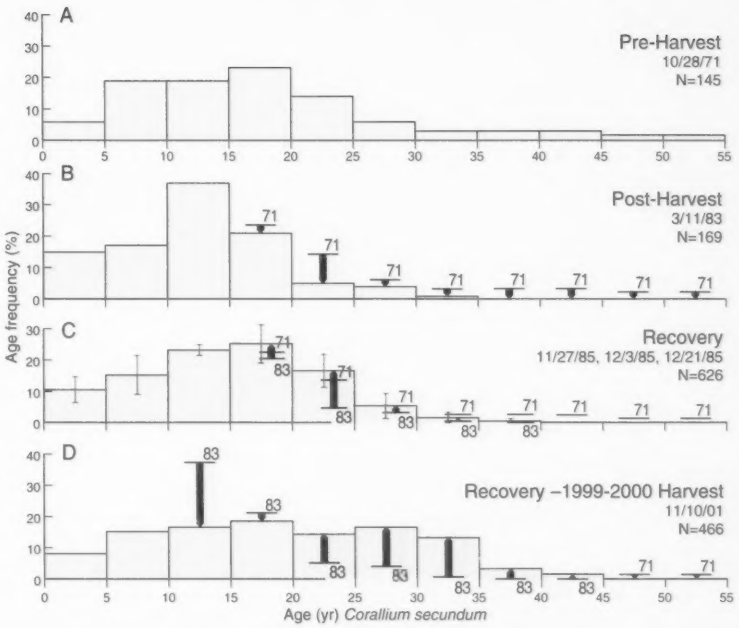

Figure 2.—Age structure (frequency distribution) of pink coral in the Makapuu Bed, Oahu, in 1971, 1983, 1985, and 2001. Arrow bars indicate relative decrease or increase in age frequency since reference year.

of the Gulland method, where MSY = $B \times m \times 0.4$ (Gulland, 1974), where B = biomass and m = mortality. Biomass estimates for *Corallium secundum* were obtained utilizing the equation $Y = 0.8x^{2.27}$ (Grigg, 1976) for converting length to weight, where Y = colony weight in grams, and x = colony height in cm. Biomass estimates for *Gerardia* sp. and *C. regale* were based on estimates of mean weight of legal size colonies measured on dive transects (4 feet for *Gerardia* and 10 inches for *C. secundum* and *C. regale*, (USDOC, 1980).

Age, for both species of *Corallium* and *Gerardia*, was determined by the relation between growth rings (assumed to be annual) and colony diameter and height (Fig. 3). Mortality was calculated as the best fit least squares regression of age class frequency plotted against age for *Gerardia* sp. (Fig. 4) and *Corallium* spp. (Grigg, 1976).

In the case of this study of *Gerardia*, growth ring counts judged to be annual produced a growth rate approximately 100 times greater than that estimated for a colony of *Gerardia* of similar size (3.1 cm basal diameter) collected at 620 m off Little Bahama Bank in the Caribbean Sea (Druffel et al., 1995). Growth bands (or laminations) counted in the Caribbean *Gerardia* were also assumed to be annual in periodicity, but, in that case, counts produced a colony age of 1,350–2,700 years. Carbon dating of the trunk of the same colony produced an age of 1800 years ± 300 years. The Druffel et al. (1995) estimate of growth and age cannot be correct for Hawaiian colonies of *Gerardia* because it would produce a wholly unnatural age-frequency distribution lacking in recruitment for many recent decades (Fig. 4). Missing recruitment for this many years is highly improbable, especially given our recent observations of moderately high recruitment in the Makapuu Bed (see below). More likely, the assumptions made in the Druffel et al. study (1995) are probably incorrect. Their growth bands more likely represent growth over several days. Their carbon dates may be skewed by colonies feeding on old particulate carbon. Or,

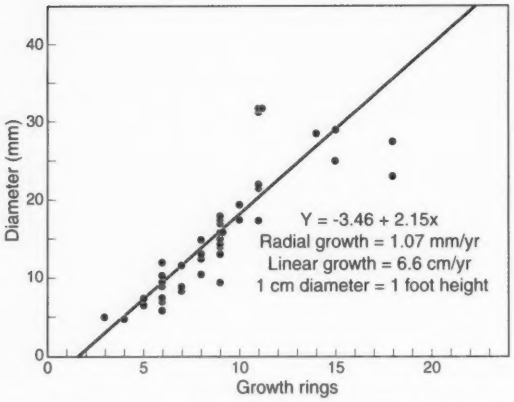

Figure 3.—Relationship between growth rings (assumed to be annual) and colony diameter for *Gerardia* sp. A radial growth rate of 1.07 mm/yr was found to be equivalent to a linear rate (annual increase in height) of 6.6 cm/yr. The linear rate was used to convert size frequency to age frequency in Figure 4.

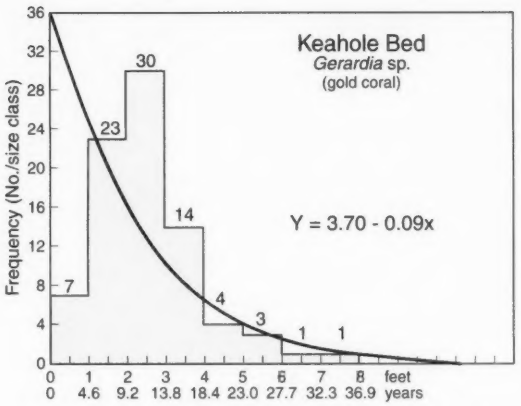

Figure 4.—Age frequency of gold coral in the Keahole Bed, Hawaii showing mortality rate beginning at larval settlement (recruitment to the bed).

isotopic exchange between the skeleton and seawater may have occurred. It is not likely that the growth rate of *Gerardia* growing at similar depths in the Pacific and the Atlantic would differ by two orders of magnitude. Clearly, more research on the ecology of *Gerardia* is needed before this discrepancy can be rectified.

Results and Discussion

Estimates of both the bed area and MSY were revised upward for the Makapuu and Keahole Point Beds based on the data produced by Pisces IV dives and ROV data collected in 2000–01. A new, large bed of *Gerardia* sp. and *C. regale* was also discovered on the summit of Cross Seamount. Patterns of distribution and abundance of both species on Cross Seamount are described and preliminary estimates of MSY are given.

Makapuu Bed

The November, 2001 surveys of the Makapuu Precious Coral Bed, consisting of two Pisces IV dives and two ROV/RCV-150 transects, produced several new and surprising results. Transect lines covering 11 linear km crossed and defined the edges of the bed at all boundaries to the north, south, east, and west (Fig. 1, 5). The area of the bed (4.3 km^2) was found to be 20% larger than previously estimated (Grigg, 1976). Also, the mean density of *C. secundum* was found to be 0.30 colonies/m^2 ± 0.03 SD in 2001 vs 0.022 colonies/m^2 ± 0.03 SD in 1971. The product of these differences (1.2 × 1.3) produces an overall abundance of about 1.5 times greater than that originally used to estimate MSY (Grigg, 1976), thus yielding an MSY ~50% greater than originally calculated, e.g. ~1,500 kg/yr. The surveys in the early 1970's were all within the same boundaries outlined in Figure 5.

Another positive result, from a management standpoint, was an increase in the percent of older year classes of *C. secundum* in 2001 compared to surveys in 1971 and 1983 and 1985 (Fig. 2). Year class groups of 20–25, 25–30, 30–35, 35–40, and 40–45 years, all increased in relative abundance over the same year classes in 1983, showing substantial recovery from the harvest years in the 1970's. Even though all year class groups in 2001 had not fully recruited (e.g. year classes 45–50 and 50–55 were still under-represented), the middle size colonies in 2001 were relatively more abundant and present in greater density compared to 1971 (Fig. 2), making the overall biomass in the bed 45% greater in 2001 than 1971. In terms of biomass, recovery in 2001 exceeded 100%. This result is due to the greater percent of older and larger colonies in the age-frequency distribution of the population.

The relative increase in older, larger colonies of *C. secundum* raises the question as to how this might have come about. Examination of the age structure in 1983 shows a strong year class group between years 10 and 15. This would have taken place when *C. secundum* recruited from larval settlement in the early 1970's at a time when submersible harvest began. The act of harvesting colonies may have triggered the release of larvae, or, alternatively, and perhaps more likely, the harvest (removal) of large coral colonies from the population may have caused their natural predators, such as *Eucidarid* sea urchins, to disperse, thereby lessening mortality especially to young colonies. In other words, *C. secundum*, may have increased in abundance due to increased survival of recruits in the 1970's due to reduced predatory pressure. During the 2001 survey, only 5% of all colonies measured (466) showed any signs of predation (broken branches or the presence of the grazing sea urchin, *Steriocidaris* sp.). The strong year class

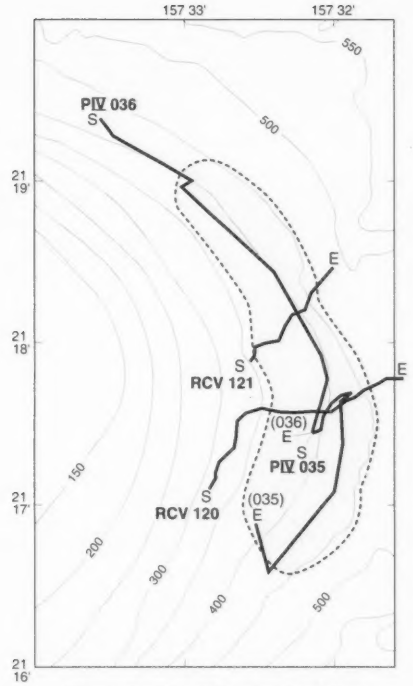

Figure 5.—The Makapuu Coral Bed showing the location of 2000–01 submersible dives and ROV transects.

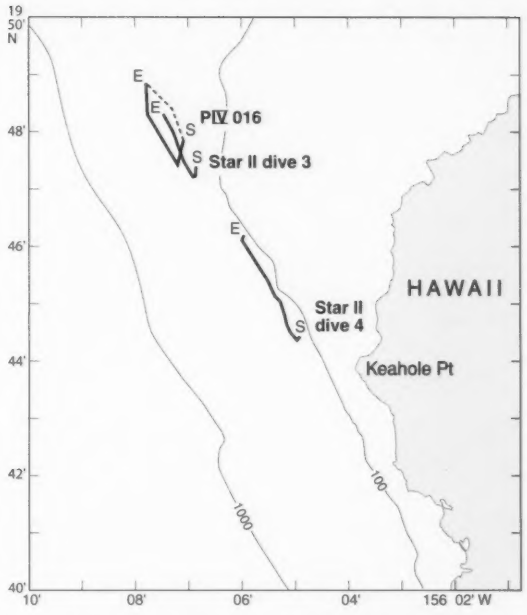

Figure 6.—Precious coral bed off Keahole Point, Hawaii. Bed is circumscribed by track of dive PIV 016 and dashed line. Track of PIV 031 all within prescribed area of the bed.

group in 1983 may have resulted from reduced mortality.

Another positive result regarding the management of gold coral, *Gerardia* sp., was a relative increase in recruitment of young colonies in the Makapuu Bed in 2001 compared to Pisces V surveys in 1997. On dives PIV-035 and PIV-036 in 2001, 14 colonies of *Gerardia* less than 30 cm high were counted, compared to only 3 in this size range in 1997. A similar area of bottom habitat was surveyed in both of these dive series. The low recruitment of *Gerardia* in the 1997 surveys in the Makapuu Bed, prompted the Western Pacific Regional Fishery Management Council to set the harvest quota of 600 kg/2 years for *Gerardia* to zero in 1999.[2]

A final observation made during the RCV-150 transects was a huge increase in abundance of crinoids attached to colonies of *C. secundum* during hours of darkness. Virtually no crinoids were observed from the submersible during 15 hrs of observation during daylight hours, whereas, at night during the ROV transects, literally thousands of individuals were observed out in the open, clinging to branches of *C. secundum*. Some colonies supported 2–4 crinoids. Clearly, crinoid behavior during daylight hours is extraordinarily cryptic even at depths where sunlight is virtually absent.

Keahole Point Bed

The precious coral bed off Keahole Point on the Kona Coast of Hawaii (Fig. 6) was found to be 4.0 times larger (0.96 km^2) during the 2000–01 surveys than previously charted by the Star II submersible in 1975 when the bed was first discovered (USDOC, 1980). This is often the case when new surveys explore bottom area beyond the limits of area initially covered. The 2000–01 Pisces IV dives logged 16.4 hrs bottom time and covered 4 times the distance of the original Star II transect, suggesting that a longer survey would result in charting even more bed area. Therefore, the estimate of bed area is considered conservative, as are estimates of MSY given below.

The depth ranges encountered for both species were 380–410 m for *Gerardia* and 388–450 for *C. regale*. Depth boundaries were relatively sharp; however, within the bed, the abundance pattern of both species was found to be quite patchy. Nevertheless, sharp depth limits produced accurate vertical boundaries for the bed. Aggregations of *Gerardia* were particularly common along or near the tops of drop-offs while colonies of *C. regale* were aggregated more to each other than to obvious variables of the substratum. No species of fish appeared to be associated with either species of

[2]Framework Adjustments to the Precious Coral Fishery Management Plan, 9-7-99)

precious coral although bottom fishes were generally more abundant inside vs. outside the bed, probably a consequence of sharing ecological factors in common (bottom steepness, substratum rugosity, depth, current, etc.).

During the course of Dives PIV-016 and PIV-031, 83 colonies of *Gerardia* sp. (Fig. 6) and 302 colonies of *C. regale* were measured (height). Applying Gullands' equation (MSY = $B \times m \times 0.4$) and inserting estimates of B and m for *Gerardia* (Fig. 4), and *C. regale*, produced estimates of MSY of 209 and 90 kg, respectively. These values apply to a bed area of 0.96 km^2 and would be greater if the bed area was found to be larger. If dollar values (based on the ADE auctions in 2001) are applied to both species, the collective value of annual yield (if realized) would be about $162,000 (Table 2).

Table 2.—MSY values (kg) and dollar values ($k) of precious coral stocks in Hawaii.

	Pink Coral		Red Coral		Gold Coral		Total	
Bed	Amt. (kg)	Value ($k)	Amt. (kg)	Value ($k)	Amt. (kg)	Value ($k)	Amt. (kg)	Value ($k)
Makapuu	1,500	280	—0—		—0—		1,500	280
Keahole	—0—		90	79	209	83	299	162
Cross	—0—		35	31	324	130	359	161
Totals	1,500	$280	125	$110	533	$213	2,158	$603

Cross Seamount Bed

Cross Seamount is located 250 km due south of Honolulu, Oahu, and 220 km west of the Kona Coast, Hawaii. The seamount is not part of the Hawaiian Island chain per se. Rather, it is believed to have originated during the Cretaceous Era at a location about 10 degrees south of the equator (Wessel and Keating, 1994). The present location of Cross Seamount on the Hawaiian superswell south of Oahu, is a result of plate motion (Rotondo, 1980).

Precious corals were first observed on the summit of Cross Seamount during an expedition there in 1986 to assess the resource potential of ferromanganese crusts and potential environmental impacts of crust mining (Grigg et al., 1987). Submersible dives in Pisces V in the following two years substantiated this discovery, but it wasn't until the 2000–01 dive series in the Pisces IV, that the resource was fully mapped.

A total of three Pisces IV dives and one ROV/RCV-150 transect were completed during the 2000–01 dive series (Table 1). A composite high precision (10 m contour) bathymetric map of the entire summit of Cross Seamount using Seabeam was also produced during the survey (Fig. 7). Video transects of all dives and in situ observations helped to interpret Seabeam bathymetry.

The summit of Cross Seamount is star-shaped in outline and about 6 km in diameter. The geomorphology and the depth of the seamount indicated that it is a guyot. Average summit depth is about 400 m; however, scattered over the summit are numerous outcrops in the form of steep-sided volcanic pinnacles and ridges, producing up to 10–15 m of relief. The largest and shoalest of these, is an oblong bathylithic dome about 1 km northeast of the summit center-point. Its diameter and depth are 0.3 × 0.5 km and 335 m, respectively. The dome is composed of smooth but fractured basalt. In at least two places on the flanks and at the base of the dome, thin veneers of limestone were found. Samples collected in situ show it to be highly indurated fossiliferous coral, presumably killed when Cross Seamount drowned during the Cretaceous Era (Malahoff[3]).

The dome itself is unique on the seamount because of its shape and smooth contour. All of the other pinnacles and ridges on the seamount contain more vertical relief and are more highly eroded. Sea caves, probably produced by wave erosion when the guyot drowned, are common, particularly at the bases of the pinnacles and ridges, strongly suggesting the summit itself is a product of wave truncation. A thicker veneer of limestone reef may have protected the bathylithic dome from wave erosion at the time of drowning. The flat-ground on the guyot floor consists of large sand pockets alternating with low wave-worn basalt outcrops.

The extant biology surrounding the dome of Cross Seamount is also unique. As opposed to the volcanic pinnacles and ridges where colonies of *Gerardia* and *C. regale* were abundant, none were observed on the summit dome. Even more unusual was a school of six or eight extremely large Cooke spiny sharks, *Echinorhinus cookei* and six-gill sharks, *Hexanchus griseus*, all about 3 m long, that were observed on all three P-IV dives, swimming back and forth, milling over the summit. Both of these species are extremely primitive fishes, having evolved during the Mesozoic Era (Tinker, 1978). For this reason, we named the summit of Cross Seamount, "Jurassic Park."

Colonies of the precious coral *Gerardia* sp. and *C. regale* were consistently present and moderately abundant on all of the volcanic pinnacles and ridges surveyed. *Corallium secundum* was also observed but it was not abundant. Depth ranges for *Gerardia* and *C. regale* were 380–430 m and 370–445 m, respectively. During the three Pisces IV dives, which consisted of 22.5 hrs bottom time, about 7.0 km of bottom was traversed. Of 25 pinnacles and 3.3 km of ridge-line at depths suitable for *Gerardia* and *C. regale*, identified on the Seabeam map (Fig. 7), 8 pinnacles and 0.75 km of ridge were surveyed, on which counts of both species were recorded.

This area represents about 25% of the suitable habitat for both species on the guyot summit. Over this area, a total of 562 colonies of legal size (4.0 ft) *Gerardia* and 625 colonies of legal size (10 in) *C. regale* were counted. If these figures are extrapolated over the entire suitable habitat on the summit, about 2,250 legal colonies of *Gerardia* and 2,500 legal colonies of *C. regale* would result. Converting these counts to biomass and applying Gulland's equation for MSY, would give an MSY of 324 kg for *Gerardia* and 35 kg for *C. regale* coral. These estimates must be considered very approximate since

[3]Malahoff, Alex, University of Hawaii, Honolulu. Personal commun. 1987.

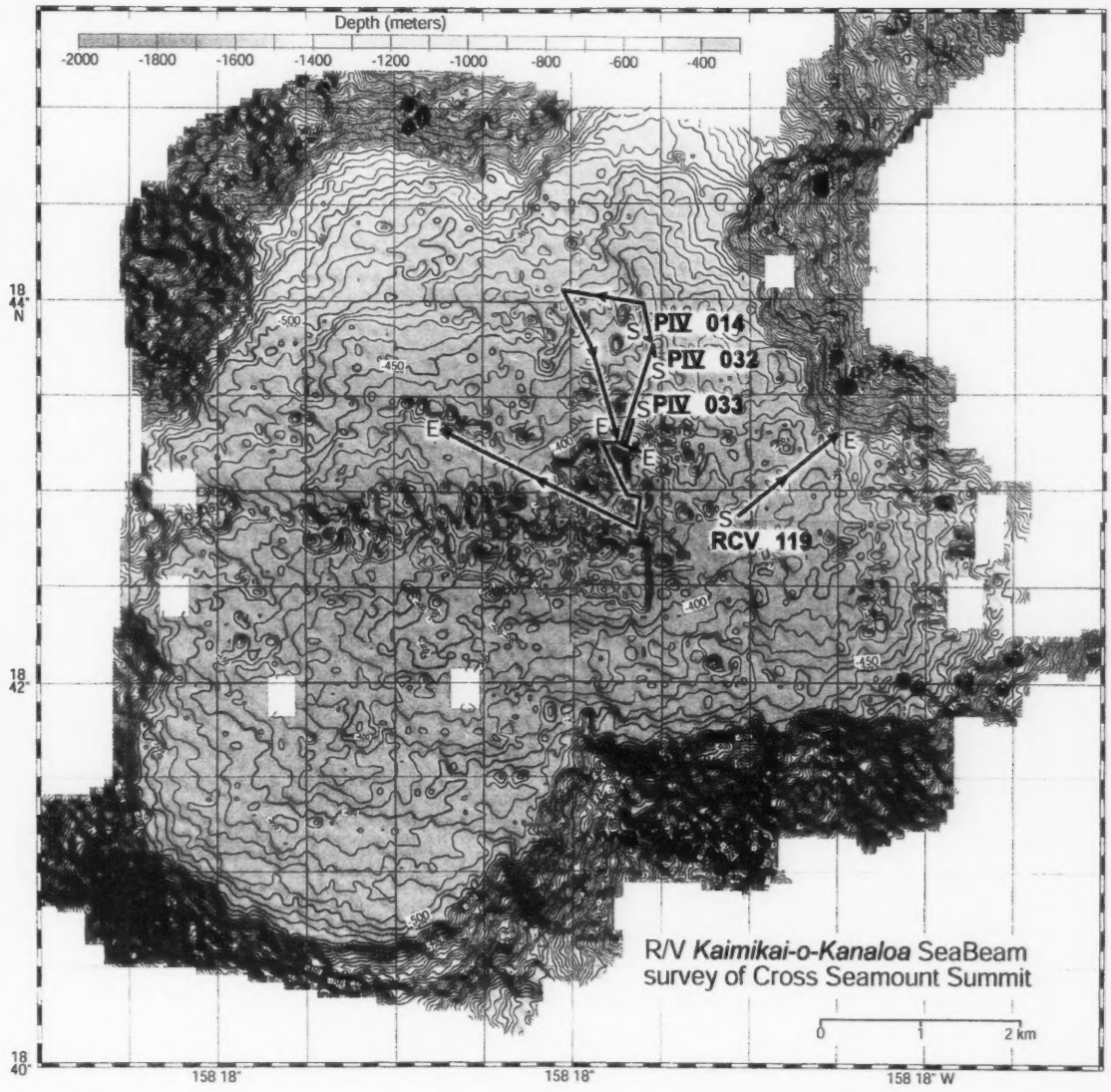

Figure 7.—Summit of Cross Seamount showing detailed bathymetry and suitable habitat of *Gerardia* sp. and *Corallium regale*. Contour interval is 10 m. The habitat of both species consists of all vertical outcroppings more than 2 m in relief on the summit of the seamount at depths shallower than 475 m.

only a small area of the summit was surveyed visually. However, the map bathymetry by which suitable habitat area was estimated appears to have good precision.

In the case of gold coral, a large number of dead colonies lying on the bottom could also be harvested. When colonies of *Gerardia* die and topple, their skeletons accumulate on the seafloor where they slowly decay. The amount available, that is still useable (slight or no decay) for the manufacture of jewelry, was judged to be at least as great as the MSY. Presumably the harvest of dead *Gerardia* would not produce negative environmental impact. Should both live and dead fractions of the gold coral be harvested, about 650 kg could be taken (at least in the first year) valued at about $250,000. Adding the value of the MSY for *C. regale* increases the total of raw coral for Cross Seamount to almost $290,000.

Conclusions and Future Prospects

The 2000–01 Pisces IV dive series to study precious coral in the main Hawaiian Islands increased the area of the two known beds off Makapuu, Oahu, and Keahole Point, Hawaii, and resulted in the mapping of a new bed at Cross Seamount. Estimates of MSY and potential dollar value of all three species of pink, red, and gold coral in each bed are given in Table 2.

The maximum sustained annual yield for all three species of precious coral in the main Hawaiian Islands is about 2 tons valued at about $600,000 for unprocessed raw coral. Given the demand expressed at the last auction held by American Deepwater Engineering in 2001 in Honolulu when 1,427 kg of all three species were sold, this supply is more than adequate to meet the needs of the small precious coral industry in Hawaii.

A serious problem that continues to plague the industry is the cost vs. benefit of harvesting the resource. The depths where deepwater precious corals are found, the surface weather where beds exist, and the legal requirement for selective harvest, all require that submersible or ROV technology be utilized. Harvesting costs are more or less fixed. The only way the supply side (harvesting) of the industry can survive is for prices of raw coral to increase, and/or for demand to increase. However, because the price structure is set by world market forces and supply is available from foreign sources, these changes are not likely to occur at least in the short term. The deepwater precious coral fishery in Hawaii may, therefore, remain dormant until market forces change. The same economics do not apply to the black coral fishery in Hawaii. A balance between supply and demand for black coral now exists and the fishery continues to be well managed by Federal and state agencies (Grigg, 2001).

In spite of economic uncertainties, scientific research dealing with precious coral species continues to produce new and important findings (Grigg, 2001; Parrish et al., 2002; Grigg et al., 2002). The deep reef where Hawaii's precious corals are found is essentially a mare incognitum, where almost every submersible dive produces new biological discoveries. The geology of the deep shelves, seamounts, and guyots, around Hawaii are also poorly studied. The presence of drowned fossil reefs in this environment hold clues to the sea-level history as well as the subsidence or uplift history of individual islands and submerged volcanoes. Citing one example, the drowning of the fossil coral reef that now veneers the summit of Cross Seamount may indicate that sea-level change in the Cretaceous Era may not have been much different than the last 20,000 years (The Holocene Transgression), when one-third of all atolls in the Pacific Ocean drowned (Menard, 1986).

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Species Composition, Catch Rates, and Size Structure of Fishes Captured in the South Florida Lampara Net Fishery

RICHARD S. MCBRIDE and JUSTIN R. STYER

Introduction

South Florida's lampara net fishery has been a small but valuable bait fishery targeting halfbeaks (Hemiramphidae) for more than a half century (McBride, 2001). The two primary target species, ballyhoo, *Hemiramphus brasiliensis*, and balao, *H. balao*, are short-lived, fast-growing pelagic species (Berkely and Houde, 1978; McBride and Thurman, 2003). Little attention has been paid to the overall catch composition of this fishery, although Berkeley et al. (1975) and McBride et al. (1996) reported that only needlefishes (Belonidae) and flyingfishes (Exocoetidae) consistently occur with halfbeaks in these catches.

There are three reasons to examine the species composition, catch rates, and size structure of fishes captured in the south Florida lampara net fishery. First, the effect on catch composition, resulting from the recent geographic expansion of this fishery, has not been examined. In the early 1990's this fishery expanded from the Atlantic Ocean into Florida Bay (Fig. 1; McBride, 2001), and it seemed likely that catches from lagoon and bank habitats of Florida Bay would differ in some manner from catches from the historical fishing areas, which are Atlantic Ocean reef habitats. Second, markets for and landings of flyingfishes appear to be expanding, and this part of the fishery should be examined. Although a flyingfish fishery is mostly of local interest, it shows that fishery markets continue to develop in the southeastern United States. Last, bycatch in any fishery represents waste that should be described, monitored, and managed carefully (Alverson and Hughes, 1996; Schmitten, 1998; Boreman, 1998).

Because the term bycatch has been used in several ways, it deserves clarification here. Hall (1996) categorized all animals captured by fishing gear in one of three ways: catch, bycatch, or released. Catch consists of target and nontarget species that are kept onboard to be sold later. Unsold catch, rejects, or processing waste are treated as separate categories of catch by Hall (1996). Bycatch comprises target and nontarget fishes that are discarded as dead (or likely to die) at sea because they have little or no economic value or keeping them is not legal. In contrast to bycatch, released fish are those returned to the sea that can be expected to survive. Fish that are not captured, yet die because of fishing operations, are not categorized as bycatch by Hall (1996) but as collateral mortalities. The above terminology is used in interpreting the results of this study.

This study describes the complete species composition of the south Florida lampara net fishery. We examined the landings data reported by this fishery since 1986, although these data were limited because fish sizes, bycatch, and released species did not have to be reported. To overcome this limitation in the reported data, a biologist collected data while onboard commercial fishing vessels, during normal fishing operations in the years 1995–99, as part of a cooperative program with the lampara net fishing industry.

Materials and Methods

Since 1986, transactions between a harvester and a wholesale dealer for marine organisms landed within Florida have been required by law to be reported to the Florida Fish and Wildlife Conservation Commission. The processed data concerning these transactions are maintained in the Florida Marine Fisheries Information System (MFIS).

Halfbeak landings (i.e. undifferentiated hemiramphids) in pounds, deter-

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ABSTRACT—Reported landings for the years 1986–2001 and recent data from onboard observations (1995–99) were examined to describe the catch composition, including bycatch, of the south Florida lampara net fishery. Landings of the primary target species, ballyhoo, Hemiramphus brasiliensis, *and balao,* H. balao, *have remained stable since 1986. Ballyhoo is the dominant species in the catch, particularly during winter months when lampara net catch rates are highest. However, since the inshore fishing areas were closed to lampara nets in 1995, more balao are landed by the fishery because balao are more abundant than ballyhoo in offshore waters. A new market for flyingfishes (Exocoetidae) has emerged, and landings of flyingfishes have steadily increased in the last decade. Balao and flyingfishes are more abundant in lampara net landings during the summer. Needlefishes (Belonidae) are regularly caught but have not been marketed successfully. The amount of bycatch in the lampara net fishery is very low compared to that in other commercial fisheries. Fishing with lampara nets in Florida Bay, which developed during the early 1990's, is different than fishing in the Atlantic Ocean. In Florida Bay, balao and flyingfishes do not occur, halfbeaks (Hemiramphidae) other than ballyhoo and balao are occasionally caught, benthic species appear frequently in the catches, reported catch rates are higher than in the Atlantic, and ballyhoo are larger on average than in the Atlantic.*

mined from Florida's MFIS data, were summarized previously (McBride et al., 1996; McBride, 2001), but herein these landings are reported as the number of individuals harvested. Landings for the south Florida lampara net fishery were typically reported "by the piece" (i.e. individual fish). Bulk weights of halfbeaks were reported separately (Table 1), and we converted these bulk values to numbers by using an average of 5.7143 halfbeaks/lb (12.572 halfbeaks/kg, from McBride, 2001). This is a conservative estimate of the number of halfbeaks sold in bulk, because halfbeaks that are reported by weight are generally small or damaged fish.

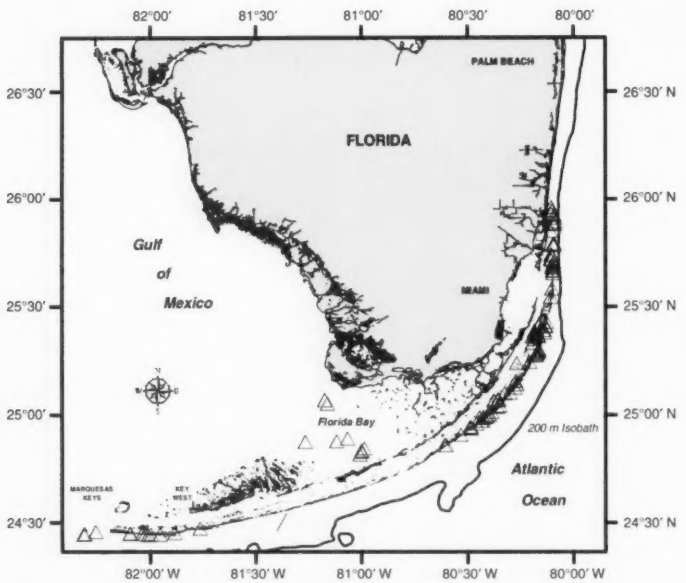

Figure 1.—Map of south Florida identifying the major fishing areas of the lampara net fishery. The fishing grounds were distributed in the Atlantic Ocean prior to the 1990's and fishing expanded into Florida Bay during the early 1990's. Triangles indicate locations of observed lampara net sets by commercial fishing vessels during the period July 1997–October 1998.

Table 1.—Annual reported landings (in numbers of fish [*n*] or pounds) and number of day trips in which halfbeaks (Hemiramphidae), flyingfishes (Exocoetidae), and needlefishes (Belonidae) were caught in the south Florida lampara net fishery since 1986. Total number of halfbeaks landed was estimated by converting additional pounds into numbers, assuming an average of 5.7143 halfbeaks per pound (from McBride, 2001), and adding that to the reported number of fish sold as individual fish. A fishing year of July–June is used. Data source: Florida's Marine Fisheries Information System. Data for 2000–01 are preliminary.

	Halfbeaks				Flyingfishes			Needlefishes	
Fishing Year	*n*	Additional pounds	Total *n*	Day trips	*n*	Additional pounds	Day trips	*n*	Day trips
1986–87	4,057,778	206,517	5,237,878	1,151					
1987–88	5,938,096	156,636	6,833,161	1,530					
1988–89	5,679,168	171,884	6,661,365	1,565					
1989–90	6,762,960	121,742	7,458,630	1,411					
1990–91	6,092,953	149,164	6,945,321	1,379	1,268		6		
1991–92	9,002,342	186,720	10,069,316	1,603	4,352		19		
1992–93	4,836,715	156,289	5,729,797	1,059	8,077		27		
1993–94	7,902,374	172,051	8,885,525	1,313	13,777		66		
1994–95	8,066,121	151,259	8,930,460	1,301	5,625		28		
1995–96	7,197,303	157,304	8,096,185	1,215	66,474	2,336	106	32	13
1996–97	4,578,287	68,229	4,968,168	814	27,029	1,959	64		
1997–98	5,466,287	106,652	6,075,729	915	80,918	2,210	104	924	7
1998–99	9,172,621	129,285	9,911,394	1,145	51,255	578	77		
1999–2000	3,899,987	57,464	4,228,354	789	41,050	4,096	58	6	1
2000–01	6,054,111	38,113	6,271,900	836	98,795	48	104		

Bulk weights of flyingfishes were also kept separate from the numbers of flyingfishes landed, but these weights were not converted to numbers of fish. Flyingfishes sold by the piece were not identified to species, but they are typically one of two genera, *Exocoetus* or *Cypselurus*. Flyingfishes sold by weight were generally a different and smaller species, (sailfin flyingfish, *Parexocoetus brachypterus*), or damaged *Exocoetus*/*Cypselurus*.

A variety of needlefish species (Belonidae) were captured, with only a few sold by the piece, and no bulk sales of needlefish were reported. Fishing-effort information from Florida's MFIS was reported as day trips or converted to day trips from multiple-trip records. Annual landings were aggregated by a fishing year, July–June, because peak catches of the primary target species (ballyhoo and balao) occurred during winter. Catch rates were calculated as the geometric mean number of halfbeaks landed per fishing day (i.e. backtransformed values of $\log_e$-transformed data; Sokal and Rohlf, 1981).

Commercial lampara net fishing trips were monitored by an onboard biologist during as many as four trips per month, from November 1995 to April 1999. A subsample of every observed set was obtained by filling a 20-l bucket as the catch was transferred from the net to holding boxes. This bucket could hold 100–200 individuals, and all collected fishes were measured to the nearest mm fork length (FL; from the tip of the upper jaw to the fork of the tail). In addition, fishes from the first set of every fishing day were kept on ice and brought back to the laboratory, where lengths and weights were measured for up to 30 fish of each sex for each species. Whole body weight was recorded to the nearest 0.1 g. Most weight measurements were made during the period July 1997–October 1998. Species-specific length-weight conversion equations were estimated by linear least-squares regression of

log-transformed fork lengths and body weights, and these equations were used to calculate weights for fish that were measured only for FL. A student's *t*-test was used for each statistical test of fish sizes and evaluated at $P < 0.01$ (Sokal and Rohlf, 1981).

Results

Fishery Landings

Since 1986, the estimated total number of landed halfbeaks has ranged from 4.2 to 10.1 million fish annually (Table 1). Halfbeak landings were highest in 1991–92, but have fluctuated considerably between years. The reported number of trips during which halfbeaks were caught reached a high of 1,603 day trips during the year of peak landings, 1991–92, and fell to a low of 789 day trips in 1999–2000 (Table 1). Reported catch of halfbeaks per trip was consistently higher in Florida Bay fishing grounds compared to the Atlantic Ocean (Fig. 2). Species composition of halfbeak landings were not reported to Florida's MFIS, but they were identified through interviews with industry participants. In general, these landings were dominated by ballyhoo and the balance of halfbeak landings were balao. The silverstripe halfbeak, *Hyporhamphus* sp.[1], occasionally occurred in Florida Bay catches, and all other hemiramphid species were rare.

Landings of flyingfishes were not reported until the early 1990's (Table 1). Flyingfish landings have increased dramatically from 1,000 to nearly 100,000 fish annually. The number of day trips reporting flyingfish landings has increased during the past 11 years from as few as 6 in 1990–91 to more than 100 in recent years (Table 1). Flyingfish landings occurred only in Atlantic Ocean fishing grounds and were highest in the summer (Fig. 2). Although flyingfish landings were not reported by species, interviews indicated that nearly all flyingfishes reported by number of fish were larger species of two genera (*Cypselurus* and *Exocoetus*), whereas flyingfishes landed in bulk were either damaged fish (*Cypselurus* or *Exocoetus*) or a smaller species, sailfin flyingfish.

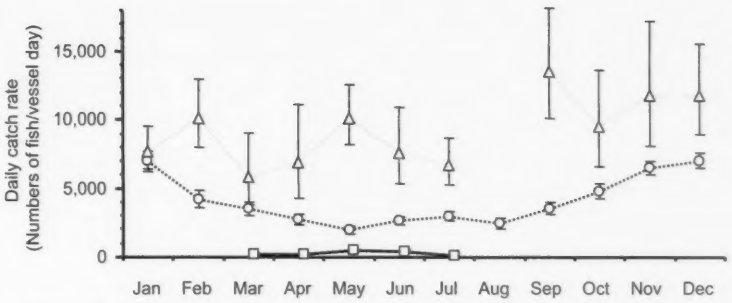

Figure 2.—Daily catch rates (numbers landed per fishing vessel day) of the primary target species (Hemiramphidae and Exocoetidae) in the south Florida lampara net fishery. Catch rates for halfbeaks (*Hemiramphus* spp., *Hyporhamphus* sp.) in the Atlantic Ocean (circles) and Florida Bay (triangles) fishing grounds are shown separately. Flyingfishes (*Cypselurus* sp., *Exocoetus* sp.) were reported for the Atlantic Ocean only (squares). Catch rates are geometric means ± 95% confidence limits for each calendar month calculated from data for the 5-year period July 1996–June 2001. Only the months in which > 30 observations per taxa were reported are shown. Data source: Florida's Marine Fisheries Information System.

All other fish species reported in south Florida lampara net landings appeared to be not targeted. Needlefishes were caught consistently throughout the year, but needlefish landings have been reported for only 3 years and have totaled less than 1,000 fish per year. Interviews indicated that needlefish species commonly landed were flat needlefish, *Ablennes hians*; agujon, *Tylosurus acus*; and houndfish, *T. crocodilus*. Reported landings identified blue runner, *Caranx crysos*; shrimp, Penaeidae; and bigeye scad, *Selar crumenophthalmus*, as uncommon, and all other species were either rare or reported in miscellaneous categories such as "baitfish" or "industrial fish" (Table 2).

Table 2.—Top ten categories of catch reported as landed in the south Florida lampara net fishery during the 10-year period July 1991–June 2001. Halfbeaks are listed for both trips that reported landings as individual fish (numbers) and by weight (pounds). Frequency is the total number of daily trips that reported catching each category of landings. Percent of each category caught is also given. "All other categories," a total of 24 different fish categories, were mostly single reports of individual species. Data source: Florida's Marine Fisheries Information System.

Category	Frequency	Percent
Halfbeaks (no.)	17,613	74.76
Halfbeaks (lb.)	4,679	19.86
Flyingfishes (no.)	544	2.31
Miscellaneous baitfish (no.)	332	1.41
Flyingfishes (lb.)	70	0.30
Blue runner	65	0.28
Miscellaneous baitfish (lb.)	54	0.23
Miscellaneous industrial fish	49	0.21
Miscellaneous shrimp	45	0.19
Bigeye scad (lb.)	22	0.09
All other categories	86	0.37

Onboard Observations

A biologist was aboard on 107 lampara net fishing trips in south Florida, and 225 sets were witnessed from November 1995 to April 1999. Both ballyhoo and balao were caught in the majority of sets (n=137), but the catches were dominated by ballyhoo in terms of both numbers (Table 3) and weight (Fig. 3). Only ballyhoo (no balao) were caught in 60 sets. Only balao (no ballyhoo) were caught on six sets in the Atlantic Ocean, and balao was never collected in Florida Bay. Neither ballyhoo nor balao were caught in the remaining 22 sets.[2]

In Atlantic waters, ballyhoo and balao dominated the catches (Table 3, Fig. 3). Needlefishes (flat needlefish, *Ablennes hians*; keeltail needlefish, *Platybelone argalus*; agujon, *Tylosurus acus*; and houndfish, *T. crocodilus*) were common year-round. Flyingfishes (*Cypselurus* sp.;

[1]A new species, *Hyporhampus meeki*, was reported by Banford and Collette (1993). We did not distinguish between *H. unifasciatus* and *H. meeki*.

[2]Although sets are made only after visually scanning the water surface for high densities of fish, on occasion a set will yield no fish. This typically occurred when rapid currents collapsed the net or equipment failure cut short the set.

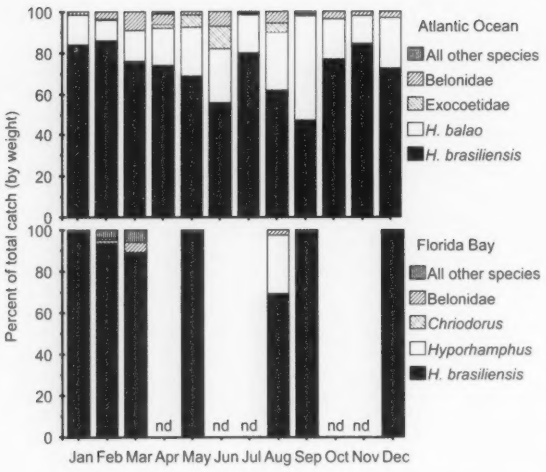

Figure 3.—Percent composition of the catch, by species or family, in the south Florida lampara net fishery (1995–99) based on data provided by onboard observers. Data are shown separately for the Atlantic Ocean (above) and Florida Bay (below) fishing grounds. Ballyhoo, balao, silverstripe halfbeak, hardhead halfbeak, flyingfishes (Exocoetidae: *Cypselurus, Exocoetus, Parexocoetus*); and needlefishes (Belonidae: *Ablennes, Platybelone, Strongylura, and Tylosurus*) are reported separately. All other species are combined. No data=nd.

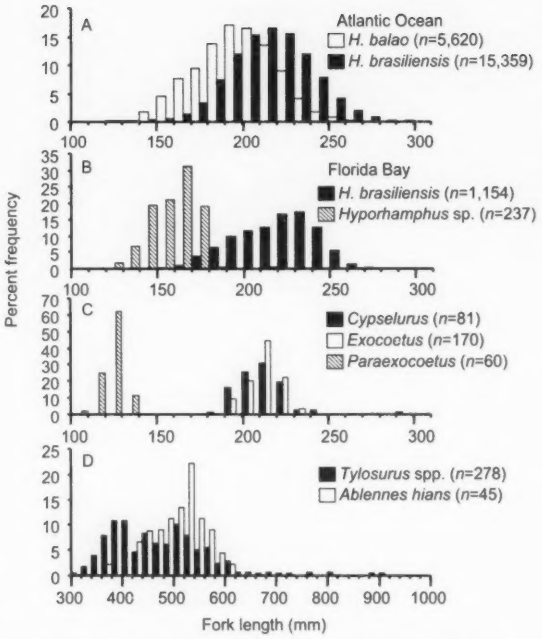

Figure 4.—Fork-length frequencies of target and selected nontarget species captured in the south Florida lampara net fishery (1995–99). A) Ballyhoo and balao captured in the Atlantic Ocean fishing areas. B) Ballyhoo and silverstripe halfbeak captured in Florida Bay fishing areas. C) Flyingfishes (*Cypselurus sp., Exocoetus sp., Parexocoetus brachypterus*) captured in the Atlantic Ocean fishing areas. D) Needlefish (*Ablennes hians, Tylosurus* spp.) captured in the Atlantic Ocean fishing areas. Sample size=*n*.

Exocoetus sp.; and sailfin flyingfish) were common during the summer. All other species caught in Atlantic waters were uncommon or rare. Several leatherjackets (*Aluterus* sp.; gray triggerfish, *Balistes capriscus*; fringed filefish, *Monacanthus ciliatus*; and planehead filefish, *M. hispidus*) were caught, but these were all juveniles and were mostly caught in a single haul that contained an unusual amount of the macroaglae *Sargassum*. Jacks (blue runner, *Caranx crysos*; bar jack, *C. ruber*; and juvenile *Seriola* sp.) and herrings (scaled sardine, *Harengula jaguana*; and Spanish sardine, *Sardinella aurita*) were rare. Individual smallwing flyingfish, *Oxyporhamphus micropterus*; Bermuda chub, *Kyphosus sectatrix*; and green razorfish, *Hemipteronotus splendens,* were observed only once.

In Florida Bay, aside from the dominant proportions of ballyhoo, only the silverstripe halfbeak[1], was found in appreciable numbers (Table 3; Fig. 3). Herrings (Atlantic thread herring, *Opisthonema oglinum*) and needlefishes (redfin needlefish, *Strongylura notata*; and *Tylosurus* sp.) were found in about half the catches in Florida Bay and were relatively common numerically. The pelagic species hardhead halfbeak, *Chriodorus atherinoides*, and leatherjack, *Oligoplites saurus*, were not common, and the scrawled cowfish, *Lactophrys quadricornis*; the striped burrfish, *Chilomycterus schoepfi*; and the great barracuda, *Sphyraena barracuda*, were all observed only once. Several demersal species were netted in Florida Bay (i.e. *Eucinostomus* sp.; *Calamus* sp.; pinfish, *Lagodon rhomboides*; and white grunt, *Haemulon plumieri*), which indicated that the lampara net commonly tended the substrate in this shallow, lagoon system.

Ballyhoo and balao sizes overlapped broadly, but ballyhoo were bigger in general (Fig. 4A). Ballyhoo were also larger than silverstripe halfbeak[1] in Florida Bay, where these species both occurred (Fig. 4B). There were seasonal, geographic, and sex-specific size differences observed for ballyhoo and balao. First, the size-structure of both species changed rapidly between months (Fig. 5). Age-0 ballyhoo recruited to the fishery in June and age-0 balao recruited in August. Geographically, ballyhoo were significantly larger in Florida Bay than in the Atlantic (Figs. 4A, B, 6). And female halfbeaks were significantly larger than male conspecifics (Fig. 6). The pattern of larger ballyhoo in Florida Bay, compared to the Atlantic Ocean, was at least partly the result of skewed sex ratios (i.e. nearly double the number of females; Fig. 6) in Florida Bay catches.

The larger flyingfishes, *Cypselurus* and *Exocoetus*, were similar in length to halfbeaks (Fig. 4C), although they were

heavier than halfbeaks at a common length. The average weight of 72 specimens (*Cypselurus* and *Exocoetus*; range: 193–231 mm FL) was 119.2 g; this is 50% heavier than the average weight of halfbeaks (*Hemiramphus* spp.; 79.5 g/fish; McBride, 2001). The sailfin flyingfish was much shorter—and the needlefishes (*Tylosurus* and *Ablennes*) were much longer—than halfbeaks or *Cypselurus/Exocoetus* (Fig. 4C, D).

Discussion

The catch of the south Florida lampara net fishery consists of four target species and at least five nontarget species. The target species are sold by the piece as bait, whereas the nontarget species are marketed in different ways as bait. Ballyhoo and balao were the primary target species historically and still are today. They are both marketed only as "ballyhoo." These halfbeaks are either sold fresh (on ice directly from the day's catch), or they are sorted by size, vacuum-packed by number (i.e. 1–12 per pack), and flash-frozen for retail sales later. Processing and grading, and the markets for ballyhoo and balao have changed little since being described by McBride et al. (1996).

During summer months, balao becomes more common than ballyhoo, but daily catch rates of both halfbeak species are low, so the overall value of the fishery drops. This is a predictable seasonal trend and most boats even take time off during the late summer months (McBride et al., 1996; McBride, 2001). The two larger flyingfishes (*Cypselurus* sp. and *Exocoetus* sp.) that have been targeted in recent years help augment the fishermen's summer incomes when catches of halfbeaks are low.

The larger flyingfishes are vacuum-packed by number and flash-frozen, and like the *Hemiramphus* halfbeaks, some are sold rigged with heavy wire leaders and single or multiple hooks. The silverstripe halfbeak[1], are not targeted, but they are occasionally taken in Florida Bay and processed by the piece. The hardhead halfbeak, *Chriodorus atherinoides*, and sailfin flyingfish are also not targeted but are caught incidentally and sold primarily in bulk. None of these nontargeted species constitute a consistent proportion of the market.

Table 3.—Species composition of catches made in the Atlantic Ocean and Florida Bay from data compiled by onboard observers of the south Florida lampara net fishery during 1995–99. Frequency refers to the number of individual sets observed (a total of 205 sets in the Atlantic Ocean and 20 sets in Florida Bay). Number indicates the total count of individuals from subsamples of the catch, and percentages were calculated from these numbers of fish by each fishing area. Hemiramphidae are identified to species (except that the silverstripe halfbeak refers only to *Hyporhamphus* sp.), and other fishes are grouped by family. Family and common names are from Robins et al. (1991) and Collette et al. (1984).

Fishing area	Family	Common name	Frequency	*n*	Percentage
Atlantic Ocean	Hemiramphidae	Ballyhoo	185	15,280	70.64
	Hemiramphidae	Balao	143	5,515	25.50
	Belonidae	Needlefishes	107	360	1.66
	Exocoetidae	Flyingfishes	37	360	1.66
	Balistidae	Leatherjackets	5	94	0.44
	Carangidae	Jacks	7	17	0.08
	Clupeidae	Herrings	2	3	0.01
	Hemiramphidae	Smallwing flyingfish	1	1	<0.01
	Kyphosidae	Sea chubs	1	1	<0.01
	Labridae	Wrasses	1	1	<0.01
Florida Bay	Hemiramphidae	Ballyhoo	12	1,095	73.59
	Hemiramphidae	Silverstripe halfbeak	5	330	22.18
	Clupeidae	Herrings	7	31	2.08
	Sparidae	Porgies	3	10	0.67
	Belonidae	Needlefishes	5	7	0.47
	Hemiramphidae	Hardhead halfbeak	2	6	0.40
	Carangidae	Jacks	1	2	0.13
	Gerreidae	Mojarras	2	2	0.13
	Haemulidae	Grunts	2	2	0.13
	Ostraciidae	Boxfishes	1	1	0.07
	Sphyraenidae	Barracudas	1	1	0.07
	Tetradontidae	Puffers	1	1	0.07

Attempts to sell needlefishes, such as rigging *Ablennes* or *Tylosurus* fillets and marketing them as 'trolling strips', have met limited success to date, and no belonid is targeted by the fishery. Needlefishes occur in the catch year-round and they are large enough to be seen in a pursed net so that they can be picked out alive and tossed back into the sea. However, no special effort is made to release them, and needlefishes not released end up mostly as chum or as free bait for local trap fisheries. Most of the additional nontargeted fish are small jacks (Carangidae) and herrings (Clupeidae); these are either packaged for cut bait or ground into chum. Foodfish or sportfish were generally not caught in this lampara net fishery, although there were some exceptions, such as white grunt caught in Florida Bay.

Halfbeaks, and any co-mingled fishes, were released alive from the pursed net on occasion. During winter months, in particular, catches occasionally exceeded the number of storage boxes onboard and the excess fish captured were released from the net.[3] Catches exceeded the storage capacity onboard on a total of 5 of 107 fishing trips made during 1995–99 when an observer was onboard. These trips occurred during October–February, and on average, an estimated 1,120 lb (510 kg) of fish were released alive from the pursed net.

The target species are typically sold by the piece—if not as fresh bait, then packaged as frozen bait. Fish are sold whole, so there is no processing waste to speak of in this fishery. Halfbeaks are graded by size for market, and larger fish are more likely to be female. At this time, sex-specific size differences (data herein and Berkeley and Houde, 1978) have not been identified as a management issue. Fish smaller than about 180 mm FL, which present more of a concern in terms of growth overfishing, are sold in bulk along with damaged fish. These smaller-sized fish are frequently encountered during June–September. They can be avoided by fishermen who spot them from the boat before a net is set or by fishermen who reduce their fishing effort during these months (McBride, 2001).

[3]Nearly all lampara net fishing vessels fishing in 1999 were 34–42 ft (10–13 m), so they have similar maximum storage capacity. Smaller fishing vessels reported by Berkeley et al. (1975) and McBride et al. (1996) have disappeared from the fishery.

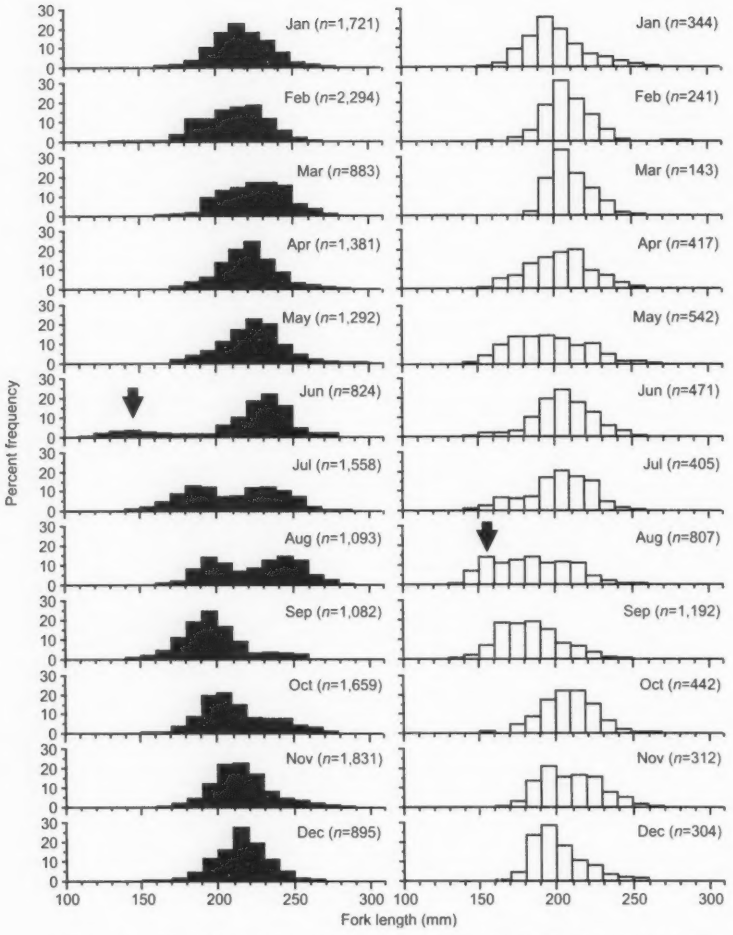

Figure 5.—Monthly fork-length frequencies of ballyhoo (filled bars), and balao (open bars), based on pooled observer data for the years 1995–99. Arrows indicate the initial recruitment event of age-0 fishes into the fishery. Sample size=*n*.

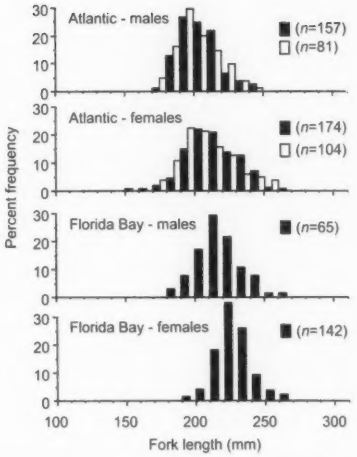

Figure 6.—Fork-length frequencies of ballyhoo (filled bars) and balao (open bars) captured during winter (December–January, 1995–99). Data are plotted by sex and by fishing area. In all three paired-sex comparisons possible, females were significantly ($P< 0.01$) larger than male conspecifics. Sample size=*n* (samples sizes are smaller than those reported in Figures 4 and 5 because not all individuals collected were identified by sex).

Both ballyhoo and balao are short-lived (Berkeley and Houde, 1978; McBride and Thurman, 2003). The annual life cycle of balao is identifiable by length-mode analysis (Fig. 5): age-0 balao recruit into the fishery in August and only a single mode progresses through the remaining annual cycle. Ballyhoo lives slightly longer (max. = 4 yr), and there is a distinctly bimodal length-frequency distribution for this species during the summer. The smaller mode represents age-0 ballyhoo, recruiting to the fishery as early as June, and rapid growth is indicated by the monthly progression of length modes. Considering this rapid turnover by both species, avoidance of smaller fish during summer reduces the potential for growth overfishing of these populations.

Lampara net fishing gear can be selective on surface-oriented fishes because the net is less than 8 ft (2.4 m) deep and designed to fish above the substrate. The method of fishing the shallow lampara nets largely avoids contact with the reef, so corals experience very little damage. The net more often contacts the substrate during fishing in Florida Bay, where depths are shallow (McBride et al., 2003). Little collateral mortality was observed except on the occasions when a stream of halfbeaks exited through a hole in the net and some individuals were eaten by reef predators such as groupers. These lampara nets are actively fished, so gear does not get lost.

The amount of bycatch in this lampara net fishery is virtually zero because of the net design, the fishing methods, and the surface-oriented behaviors of the targeted fish. In addition, most nontarget fish are processed as chum instead of becoming bycatch. For the purposes of comparisons between this and other fisheries, we determined the monthly incidental catch rate as the fish biomass of all families except Hemiramphidae and Exocoetidae as a proportion of total biomass observed in lampara net sets.

This monthly incidental catch rate was never more than 0.11 in either fishing area. On a year-round basis, the incidental catch rate was 0.037 in the Atlantic

Ocean fishing area and 0.031 in Florida Bay (Fig. 3). Most of this incidental catch is needlefish; if all needlefishes were discarded dead, the bycatch of needlefishes would average 0.036 in the Atlantic Ocean fishing areas and 0.013 in Florida Bay. In comparison, incidental catch rates are as high as 0.71 in crab fisheries and 0.84 in shrimp fisheries (Hall, 1999).

Although these ratios are relatively small for the south Florida lampara net fishery, we have not estimated the effects of this repeated biomass removal on the pelagic or reef ecosystem, nor have we calculated the biomass removal of halfbeaks or flyingfishes for bait by the commercial guides or noncommercial fishermen using small hooks or cast nets. Nonetheless, this paper offers an initial multi-species perspective of the south Florida lampara net fishery effects.

One noticeable change in the fishery since the early 1990's is the year-round presence of balao in the landings at a level much higher than reported by McBride et al. (1996). Balao, as a percentage of both ballyhoo and balao biomass from the Atlantic Ocean, ranged from a monthly minimum of 9.9% during February to a maximum of 51.1% during September during the period 1995–99. During 1988–91, however, the percentage of balao would typically be < 5% during the winter months (McBride et al., 1996). Earlier still, during 1974–75, balao were absent from catches during the winter months (Berkeley et al., 1975). This increase in balao proportions is probably due to a net-limitation regulation put into effect during the mid 1990's (McBride, 2001). Historically, ballyhoo and balao could have been targeted separately because ballyhoo occurs without balao inshore of the coral reef crest (i.e. balao occurs without ballyhoo offshore of the reef crest in south Florida; McBride et al., 2003). Ballyhoo can be considered the primary target species for the entire lampara net fishery because it grows larger, has a larger size range, and holds up better as bait during trolling than balao does. Targeting ballyhoo alone has become more difficult since 1 July 1995, because statewide regulations have prohibited lampara net fishing inshore of 1 mile on the Atlantic Ocean and of 3 miles in Florida Bay and Gulf of Mexico waters. Thus, it is likely that balao makes up a greater proportion of the catch in the past several years simply because targeting ballyhoo by fishing close to shore is no longer legal in Florida.

In conclusion, halfbeak landings by the south Florida lampara net fishery have been relatively stable since 1986, and a new source of summer revenue has developed from flyingfishes. The expansion of lampara net fishing into Florida Bay, in the mid 1990's, has brought about changes in the species composition, catch rates, and sizes of halfbeaks in the fishery. Bycatch and incidental catch rates are much lower in this fishery, particularly true for the Atlantic Ocean fishing areas, than in other fisheries.

Acknowledgments

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